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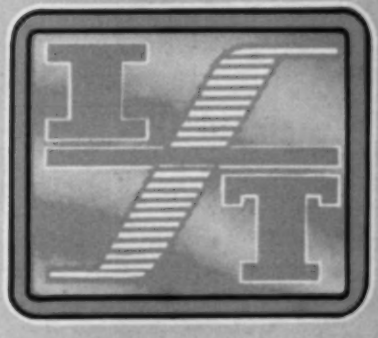

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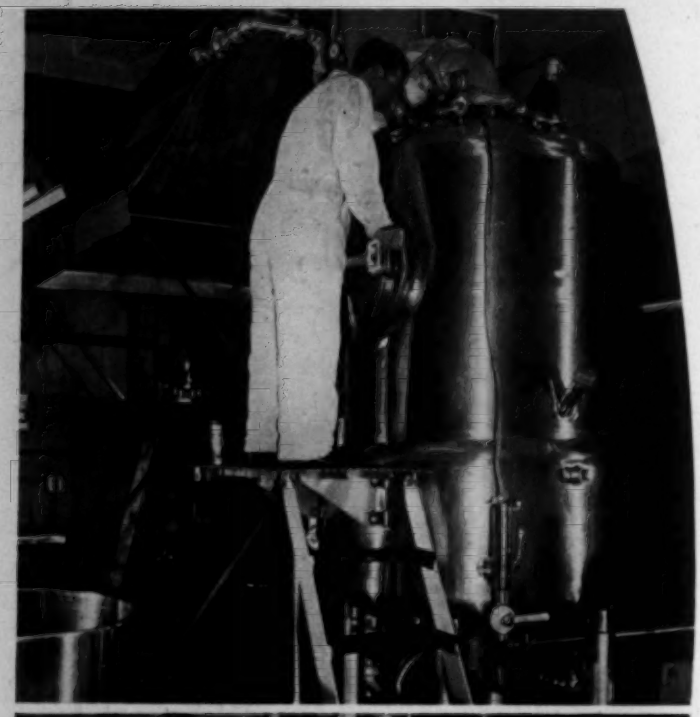

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EDITORIAL

The Additional Burden on Agriculture Caused by the Mobilization of Ten Million Citizens Into the Armed Forces[a]

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(Received for publication, May 29, 1950)

All of us, I am sure, sincerely hope that our nation will never again be faced with the actuality of mobilization for war, but we would be foolhardy indeed if we did not prepare ourselves for that eventuality. And basic to such preparation is an attempt to determine the probable additional burdens that a full-scale mobilization would place on our entire economy.

If the physical and economic demands of all major wars were the same, the problem today would not be particularly difficult. One could simply review the experiences of past wars and set forth quite convincingly the probable experiences of the next. But experience in two world wars has taught us that the physical requirements of modern warfare are anything but static, and it would be unrealistic to assume that the drain on agriculture in a hypothetical World War III could be expected to follow the precise patterns set by World Wars I and II.

There are, however, some parallels that we can safely follow; and in the following attempt to present the additional burdens that would be placed on our agricultural economy by a hypothetical mobilization of ten million citizens into the armed forces, I will first point out such parallels from the last war as I believe we are warranted in accepting, and then point out others that I believe we must reject as either completely unwarranted or highly unlikely.

We are warranted in assuming, it seems to me, that any future world war, like those of the recent past, would place an unprecedented drain on our agricultural resources. We entered World War II with very large reserves of what might be called basic war crops, the major cereals (wheat and corn), cotton, and tobacco. We had, in addition, adequate reserves of a number of other commodities. These reserves had been accumulated during the depression years of the thirties. In addition, the fertility of the land had been improved through eight years of conservation practices carried out by our farmers under the guidance of various governmental agencies.

We might off-hand conclude that we have a quite parallel situation now. Large reserves of the same basic war crops exist. Our carryover of wheat on July 1, 1950, is expected to be in the neighborhood of 450 million bushels, as compared with about 630 million bushels on July 1, 1941. On October 1 of this year we will probably have a carryover of about 900 million bushels of corn, the largest in our history. This compares with a corn carryover of only about 475 million bushels on October 1, 1941. On August 1 our carryover of cotton will approximate 7½ million bales. This is not as large as the 1941 carryover of about 12 million bales but it is nevertheless a fairly adequate reserve. And our stocks of tobacco (which I think we must view as an essential war crop from the standpoint of both military and civilian morale) are at an all-time high, and in good balance with the present high level of consumption.

So far the parallel holds. We have another parallel in the state of our essential soil resources which is roughly comparable to what it was just before World War II, despite the drain occasioned by the war. It is reasonable to assume that in case of war it will be possible to draw heavily on our conservation bank for a continued high level of production, just as we have done in the last few years.

But here, quite abruptly, the parallel ends, and a number of discouraging differences begin to appear.

When we entered World War II in late 1941, crop yields per harvested acre for the principal crops were 22 percent above the 1923-32 average. In 1942 those yields were boosted to 36 percent above that average and, except for 1943 when they dropped back to 24 percent above, the yields were maintained at 30 percent or more above the 1923-32 average throughout the war. With the tremendous postwar demands for food, and with more machinery available, yields were boosted even further until in 1948 yields of those principal crops reached the amazing level of 51 percent above average.

Offhand, that looks encouraging, but is it, actually? When World War II started we could, under the urgencies of war, step up yields and consequently the total production but in projecting food needs for a hypothetical World War III, when new and additional urgencies will undoubtedly arise, we'll have to start from where we are now. To assume any step-up in yields and production at all comparable to that brought about during World War II is to assume the distinctly improbable.

The reasons for this improbability need to be clearly understood. One of the first noticeable impacts on agriculture of World War II was the induction of farm labor into the armed services and the migration of such labor to defense industries. In 1939, when war broke out in Europe, we had 11,723,000 persons employed on farms. By 1942, soon after we entered the war, the number had been reduced by 300,000, and by the close of the war it had been reduced by 600,000 more, or a total of 900,000.

The immediate effect of this drain on the farm labor supply was a rapid shift to mechanization. In 1941, before we were actually in the war, farmers bought $638,000,000 worth of farm machinery and parts,—more than in any other year prior to the war, or than during any of the war years, for that matter. The reasons for this are not far to seek. After the United States actually entered the war, the shortage of steel forced a drastic reduction in the amount of steel available for

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 25, 1950.

farm machinery manufacture. In 1943, even though farmers would have bought many times this amount if it had been available, production of farm machinery totaled only $302,000,000. As the war progressed, however, it became apparent that if agriculture was to meet the tremendous wartime feed and fiber requirements and at the same time give up part of its manpower, an increase in the amount of farm machinery available would be necessary. As a consequence, by 1945 production of farm machinery was stepped up to the value of $613,000,000, or more than double the 1943 output and only slightly less than the output of 1941.

This step-up in farm machinery production was achieved, it should be noted, in the midst of war, and the consequent increase in farm mechanization was a very important factor in the amazing wartime increase in crop yields.

Should it become necessary to mobilize 10 million men and women into the armed forces, it is probable (1) that agriculture would have a great deal less time to get ready, (2) that there would be fewer reserves of manpower to draw on, (3) that it would have fewer reserves of animal power to draw on, and (4) that it would likely suffer a physical impairment of plant and processing and transportation facilities that it did not experience in the last war.

Let's look at each of these points. We had ample time to get ready for the last war which was under way in Europe for more than two years before we actually got into it. It is extremely unlikely that this will happen again,—not in an atomic age. War is likely to strike, if it strikes at all, quickly and where it will hurt most. With the increased range in modern aircraft, the blow will be aimed not at our physical outposts but at our industrial and economic centers. If such a blow is only partially successful there will follow the results I mentioned under (4) above: Impairment, at least, of transportation and processing facilities, and possibly, under conditions of atomic warfare, of the actual agricultural production plant itself.

As regards points (2) and (3), the figures can speak for themselves. In 1939 we had 11,723,000 persons employed on our farms, and that this number dropped by about 900,000 persons by the close of the war. Currently 10,756,000 persons are so employed despite an increase of about 15 million in our total population. In other words, as regards farm manpower, we will be starting in the event of mobilization not only at a point below where we started during the last war but at a point below the lowest point reached during that war.

The same situation maintains as regards animal power. The point is not that the loss in animal power is serious in itself. The advances in farm mechanization have more than made up for that. What is significant is that during the last war, by substituting mechanical for animal power, substantial acreages devoted to the production of animal feed could be devoted to the production of other crops, with a consequent net human food gain deriving from the loss of animal power. At the beginning of World War II we had 13,700,000 head of horses and mules on farms. By the close of the war the number had decreased to 12,000,000 and the land formerly used to feed 1,700,000 head of workstock was made available for the production of human food or for the production of feed for meat animals rather than workstock.

On January 1, 1950, we had only 7,500,000 head of horses and mules on farms, which represents a decline of 4½ million head since the close of the war. In the event of mobilization these numbers undoubtedly would continue to decline, but obviously not to the extent that has occurred since the beginning of World War II. An almost total replacement of animal power by mechanical power is not only inconceivable but undesirable from almost any point of view.

With this background of comparison between the agricultural situation in 1941 and the present time, we can begin to assess the additional burden that would be placed on agriculture by the mobilization of 10 million citizens into the armed forces of the United States.

Certain points are already obvious:

(1) Even though our supply of farm manpower is already below the lowest level of World War II, a further drain must be expected. The mobilization of 10 million citizens could not be achieved without drawing to some extent at least on our agricultural manpower, no matter how vitally it might be needed on the farms.

(2) Even though we are currently producing at the highest rate in our agricultural history, a further step-up in production to meet the urgent requirements of war would be called for. With dwindling animal power and a further decline in manpower resources, the only way to provide this step-up would be through further increases in mechanization and a further increase in crop and animal yields. To what extent this would be possible, we do not know. During the last war we were blessed with a series of years of unusually good weather. We were just at the beginning, moreover, of almost unbelievable advances in production technology, in the development of hybrid seeds, in the effective control and eradication of weeds, insects, and other plant and animal pests, and in the development of improved plant and animal strains. We can expect some further gains in all these directions (except in the weather) but it is unlikely that we could achieve gains of anywhere near the proportion we were able to achieve during and since the last war.

The interdependence of agricultural and industrial life will inescapably be greater than ever before. Any impairment of our industrial production facilities will have a greater bearing than ever before on our agricultural production. The increased mechanization of agriculture makes this conclusion unavoidable.

Production of farm machinery for domestic sale in 1948 and 1949 was at the rate of about $1,500,000,000 annually. Taking price increases into account, actual production in each of the last two years was nearly double the 1941 level. The number of tractors on farms has more than doubled since the beginning of the last war. In 1941 we had 1,823,000 tractors on farms, in 1945 2,422,000, and today between 3,800,000 and 4,000,000.

These figures not only point up the limited possibilities of further increases in mechanization as contrasted with such possibilities at the beginning of the last war, but they also show agriculture's increasing dependence on industry for maintenance and repairs of the es-

sential tools of farm production. Mechanization requires precision bearings, special alloy steels, and numerous other special items that the farmer himself cannot provide or repair and which must be available near the farm at all times if a high level of production is to be maintained.

Allied to this is agriculture's increased use of petroleum and rubber products. Consumption of gasoline and other fuels for farm tractors, farm trucks, and automobiles about doubled since 1940 and was about 6⅓ billion barrels in 1948. Before World War II few tractors and practically no other farm machinery was equipped with rubber tires. Such equipment is now essential if the farmer is to take early advantage of breaks in weather and for trucks needed to move agricultural products swiftly to market.

Also indicative of agriculture's increasing dependence on industry is its increased use of commercial fertilizers. At the close of the last war the use of these plant foods had doubled in comparison with the 1935-1939 average. In the 1948-49 period consumption rose to 269 percent of prewar. This trend will undoubtedly continue, since it is vital not only to a high yield level but also to building up a reservoir of fertility in our soils that we can draw on as it is needed.

Nor should we overlook the increased use of electrical power, which is no longer developed on our farms by small individual plants but is carried by transmission lines from central power stations. The number of farms receiving central station electric service on June 30, 1942, was about 2⅓ million, on June 30, 1949, the number had risen to more than 4½ million or 78 percent of the total number of farms.

A second point of major importance in assessing the effect on agriculture of the mobilization of 10 million citizens is the impact of such mobilization on our pattern of agricultural production.

Here the answer is none too clear. Moreover, if it were clear I would question the wisdom of discussing it in an open forum, since it involves questions of overall military strategy as regards the conduct of the war itself. In the event of war and with the mobilization of 10 million citizens, our consumption pattern would have to be changed. The direction and extent of the change would depend in a great part on the expected duration of the war, the number of people in addition to our own whose essential food requirements we might be expected to supply, and in some part on the type of warfare we might find ourselves engaged in. Our production goals under mobilization undoubtedly would be influenced by our reserve supplies of cereals, fats and oils, fibers, and livestock or livestock products, on farms or in storage at the time. They would have to be evaluated in terms of prospective needs and probable increase in exports and losses of imports.

These were important factors in the last war, and they would undoubtedly be even more important in the event of another mobilization. During the last war we exported about 21 million tons of food and other farm commodities to our allies. We also, as a result of the loss of access to the Philippines, had to increase drastically our domestic production of fats and oils. Meanwhile we decreased our production of cotton, of which we had an abundant supply.

The Lend-Lease exports of the last war entailed a large increase in our food processing facilities. Between 1940 and 1945 production of dried whole milk jumped from 29 million to 217 million pounds, a more than seven-fold increase. During the same period, production of nonfat dried milk was doubled, rising from 322 million pounds in 1940 to 643 million pounds in 1945. To bring about these increases, it was necessary to build or convert about 160 processing plants. The increase in dried egg production during this period is even more striking. From a total of 7½ million pounds in 1940, production rose to more than 320 million pounds in 1944.

The rate of increase in the dehydration of other commodities was roughly comparable to that in dried milk and eggs. This is evidenced by the fact that during the war about 170 plants were converted for the production of dehydrated fruits and vegetables, such as beets, cabbage, carrots, Irish potatoes, sweet potatoes, and tomato flakes.

These increases in dehydration facilities, it should be noted, were in addition to continued use and expansion of our normal canning facilities, even while it was necessary to reduce drastically the use of tin for food preservation purposes. Conservation of tin, which was then and continues to be a strategic and critical material, was accomplished by three related measures: First, expansion in the use of glass containers; second, elimination of non-essential uses of tinplate and the elimination of smaller can sizes; and third, utilization of lighter weight tin coatings where tin was essential. This latter, incidentally, was accomplished largely through a shift from hot dipped tinplate to electrolytic tinplate.

In concluding these remarks I feel, quite frankly, that I have pointed out a lot of figures and very few conclusions. I feel also, quite frankly, that that is as it should be. I have drawn from our agricultural experiences before and after World War II, and I have tried to relate them insofar as possible to our present situation. The conclusions necessarily reflect the indefiniteness and uncertainty of any attempt to look far ahead.

Of only one thing do I feel absolutely certain: War, by its very nature, is largely destruction and waste of men and materials, and total war,—of the type we must realistically envisage if we must envisage war in the years ahead,—is largely total destruction and waste not only of men and materials but of the society and civilization, those men and materials in the past have served to create. With the continuing and increasing integration and interdependence of agriculture and industry in our total national economy, there will be no escape for agriculture, in the event of war, from the direct effects of this destruction and waste. This we must be prepared for.

Our agricultural plant is in good shape. From the standpoint of equipment and other production facilities it is in better shape than at the beginning of World War II. But we should not be deceived by this into assuming that the miracles of agricultural production we achieved during the last war can be repeated. If they can be repeated, as I hope they can be if necessary, it will be only through an almost absolute coordination of the agricultural and industrial segments of our economy.

A Pilot Scale Study of Shell Egg Thermostabilization[a,b,c]

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A pilot scale study was made of the stabilization of shell eggs by heating in a special machine for 16 minutes under a flowing film of oil at temperatures ranging from 130° F. to 136° F. (54.4° C. to 57.7° C.). The heated eggs were examined over an 8-month storage period using untreated eggs and eggs oiled at room temperature as controls. The thermostabilized eggs retained higher quality over the storage period than did untreated and oiled eggs.

Through the centuries many methods have been devised to prolong the edibility of eggs. Among these methods is the application of heat to coagulate a thin film of albumen next to the membrane so that it acts as a moisture and carbon dioxide barrier. How long this has been practiced the authors do not know, but in 1843 "The American Poultry Book" *(3)* carried this statement: "In some parts of the south of Europe eggs are preserved by dipping them for twenty seconds in boiling water, and then keeping them well dried in finely-sifted ashes." In 1846, a note in the "Prairie Farmer" *(10)* stated: "One farmer from Michigan wrote that he was in the habit of preserving his eggs by placing them in a small basket, then dipping basket and eggs in boiling hot water for a moment. This process was repeated two or three times, after which the eggs were placed, small end down, in bran, salt or oats. This will keep them perfectly fresh and good."

In 1943 Funk *(4)* extended the idea of heat treatment to retain the initial quality by using lower temperatures and a prolonged treatment. By using a temperature below the normal coagulation point of egg albumen, and extending the time of exposure to the heat, a stabilization of the albumen was obtained. He called the process "thermostabilization" and claimed for the method: (a) An increased stability of the egg white in that it remained thick and resisted the forces of deterioration normally encountered during storage; (b) inactivation of the germ of fertile eggs; and (c) a marked reduction in the numbers of spoilage bacteria which might be present on and in the egg.

Funk *(6)* demonstrated that the process could be carried out in either oil or water at such times and temperatures as to accomplish the above advantages without altering the broken-out appearance of the eggs. In order to accomplish stabilization in eggs of different sizes, and of different initial temperatures, it was necessary to use prolonged heating at a lower temperature to obtain adequate penetration without visible coagulation. Funk *(5)* and other workers *(1, 2, 8, 9)* have reported further experimental investigations of the method.

Since it had been demonstrated that the thermostabilization of shell eggs rendered them more resistant to quality deterioration, this method seemed to offer a means of improving the marketing of eggs. Therefore, it was deemed desirable to undertake comprehensive research on the method, the keeping quality of thermostabilized products, and changes in functional values. To accomplish these ends, research was carried out cooperatively with the University of Missouri, companies handling and marketing shell eggs, and manufacturers of egg-processing equipment.

A custom-made egg-treating machine, employing the principle of a thin film of heated oil flowing over the surface of the egg shell, was chosen for the work. In this way thermostabilization of the eggs and the shell protection with oil was accomplished in a single operation. The oil used was a 50-60 viscosity oil commonly used in oil-treating shell eggs. The temperature of the oil was controlled within 1° F. (0.5° C.) by circulating it rapidly through a steam heat exchanger, equipped with thermostatic controls, and then over the surface of the eggs. The eggs were conveyed through the machine in special holders and the time of exposure to the heat regulated by the speed of the conveying device.

Stabilization for Storage

The eggs for storage experiments were obtained from a company handling eggs directly from the farm. The eggs were procured from a particular farm truck route and each lot of eggs came from the same general area, thus assuring as uniform a type of eggs as could be expected under commercial handling conditions. Upon arrival at the assembly plant the eggs were candled, all loss and checked eggs removed, and the remaining eggs packed in new packing material in new cases. These cases were then hauled 36 miles by truck to the plant where the treatment was carried out. At this point they were graded into individual cases of U. S. Grade A or better, and U. S. Grade B. Thus, each case treated contained only one grade of egg, which made it much easier to determine the rate of quality deterioration during storage.

At the suggestion of Professor Funk an exposure time of 16 minutes was chosen, and the treatment carried out at temperatures varying from 130° F. to 139° F. (54.4° C. to 59.4° C.). Eggs were passed through the machine for stabilization, placed in cases, stored over night in a cold room, and then trucked 36 miles to a commercial cold storage plant. It was believed that such handling would represent conditions reasonably comparable to the commercial practice. Certain cases of eggs were untreated to act as controls and were labeled "Naturals." Other cases were subjected to an oiling treatment at a room temperature of 85° F. (29.4° C.), labeled "Processed," and used to represent oiled eggs as found in commercial channels of egg marketing. The oil used in the latter case was the same odorless, colorless, mineral oil used in the thermostabilizing process.

Preliminary runs were made to 130° F. (54.4° C.), 132° F. (55.6° C.), 134° F. (56.7° C.), 135° F. (57.2° C), 136° F.

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 22, 1950.

[b] This study was made with funds authorized under the Research and Marketing Act of 1946.

[c] The authors gratefully acknowledge the cooperation and assistance of C. A. Swanson and Sons, Inc., of Omaha, Nebraska; the Gordon Johnson Company of Kansas City, Missouri; Professor E. M. Funk, University of Missouri, and Merwin E. Lyall, Inspection and Grading Division, Dairy and Poultry Branches, Production and Marketing Administration, U. S. Department of Agriculture.

(57.8° C.), and 139°F. (59.4° C.), to determine the effect of such temperatures on the physical appearance of the internal structures of the egg. It was found that a 16-minute exposure at temperatures of 136° F. (57.8° C.), or above, produced a progressive bluish opalescence or milky appearance and a marked thickening of the albumen. The lower temperatures produced a viscous egg white without altering the clarity. This showed that a temperature of 136° F. (57.8° C.) was the upper limit that could be used without producing a condition that would influence the acceptability of the eggs in channels of trade.

Approximately 400 cases of eggs were placed in cold storage for observation. These consisted of several cases each of "Naturals" or untreated eggs, "Processed" or oiled eggs, and eggs "Stabilized" at 130° F. (54.4° C.), 132° F. (55.6° C.), 134° F. (56.7° C.), 135° F. (57.2° C.), and 136° F. (57.8° C.). Several of the stabilized lots were placed in the cases while hot, while others were cooled below 100° F. (37.8° C.) before packing. This was to determine if under commercial conditions stabilized eggs could be packed directly into cases from such a machine, and thus avoid the delay and cost of a cooling operation.

Temperature Records

In order to determine the rate of internal heating and cooling, thermocouples were inserted in the center of selected shell eggs, attached to a potentiometer, and the temperature recorded during the passage through the machine and during the cooling period. In this way, it was possible to procure a continuous record of the heating and cooling process. Curves showing the heating and cooling of eggs stabilized between 130° F. (54.4° C.) and 139° F. (59.4° C.) are shown in Figure 1.

It will be noted that there was a steady rise in internal temperature during the heating period, and that the rise continued after the egg emerged from the machine until the maximum internal temperature was reached some 3 minutes after the application of external heat had ceased. It will be noted also that the final internal temperature of the yolk was never over 130° F. (54.4° C.), or several degrees lower than the temperature to which the albumen was exposed during the stabilizing.

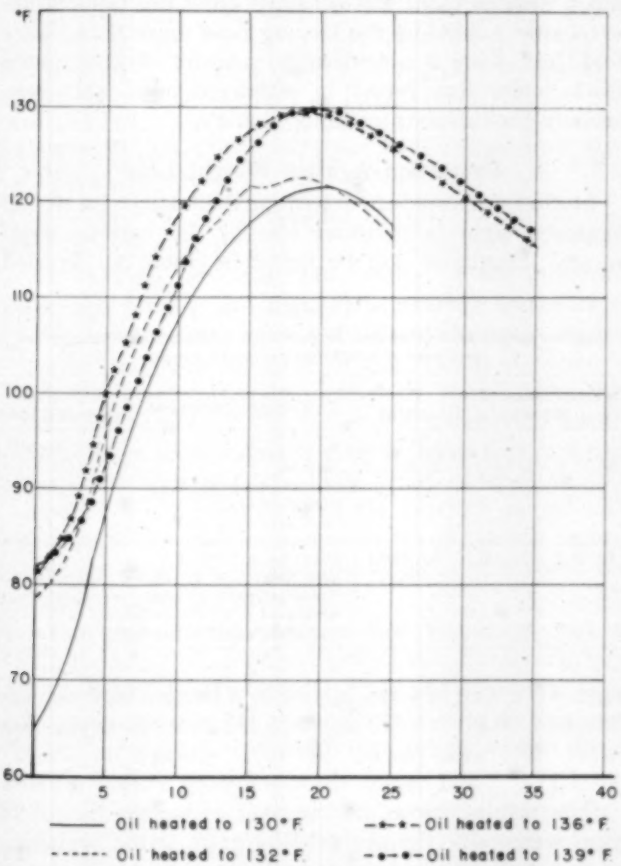

FIG. 1. Center temperatures, during a specified number of minutes, of eggs subjected to stabilization treatment for 16 minutes at various temperatures.

Internal Quality Determinations

At the time of treatment, and at intervals during the storage period, sample cases of eggs were withdrawn for quality determination by means of candle grading, and by opening eggs to observe the internal quality, albumen index, yolk index, percentage of thick and thin white, pH, and functional quality. In normal storage the proportion of thick egg white to thin egg white decreases. This condition, in which the thick white changes to thin white, results in an egg of lower interior quality, and of reduced monetary value in marketing channels.

Thick and Thin White

The amounts of the thick and thin white were obtained by measuring the total volume of the white, pouring on a standard screen, and allowing the thin white to drain through the openings for exactly 2 minutes. The volume of the thin white was measured directly and the volume of the thick white determined by subtracting the thin white measurement from the whole amount. The percentage of thick egg white in the various lots is shown in Table 1.

TABLE 1

Percentage of thick white in treated and untreated U. S. Grade A eggs after specified periods of storage

Method of treatment	Percentage of thick white in eggs after		
	4 mo. storage	5 mo. storage	8 mo. storage
	Percent	*Percent*	*Percent*
No treatment (natural)	52	44	42
Oil processed	50	46	40
Stabilized:			
130° F. cooled	....	51	48
130° F. hot	....	63	57
132° F. cooled	58	51	52
132° F. hot	65	58	40
134° F. cooled	64	....	50
134° F. hot	73	....	53
135° F. hot	....	....	68

The data show a greater retention of thick white in stabilized eggs during storage than in oiled or untreated eggs. There seems to be greater retention in eggs packed hot than in those cooled before being placed in the cases. This, no doubt, results from the "additional stabilization" resulting from the slower rate of cooling. It was noted in these studies that in general the thick white remaining in the "natural" and "processed" eggs was of poorer quality than that remaining in the eggs that were stabilized. The white in the "natural" eggs spread over a greater area, was lower in height, and was of poorer consistency.

Albumen Index

The albumen index *(7)* was determined by breaking the test eggs upon a leveled glass plate. The height of the thick albumen was measured as were the long and short diameters of its spread. The height of the thick

white divided by the average diameter of the spread gave the albumen index. The results are recorded in Table 2.

A considerable change in the albumen index during the stabilization treatment can be noted. The consistency of the albumen in the stabilized product was noticeably thicker. At the time of treatment the index

TABLE 2

Index numbers of albumen in treated and untreated U. S. Grade A eggs as determined after specified periods of storage

Method of treatment	At beginning of storage	After storage for			
		1 mo.	4 mo.	5 mo.	8 mo.
No treatment (natural)	0.054	0.056	0.053	0.048	0.047
Oil processed	0.058	0.060	0.054	0.050	0.051
Stabilized:					
130° F. hot	.....	0.085	.....	0.059	0.067
130° F. cooled	0.067	0.064	.....	0.068	0.067
132° F. hot	.....	0.108	0.068	0.061	0.067
132° F. cooled	0.078	0.064	0.072	0.068	0.070
134° F. hot	.....	0.063	0.060	0.064	0.069
134° F. cooled	0.078	0.083	0.075	0.056	0.065
136° F. hot	.....	.....	0.064	.....	0.076
136° F. cooled	0.065	.....	0.060	.....	.....

of eggs which had been packed hot was not taken. However, the results in the column headed "1 month" would indicate that the slow rate of cooling in the case brought about an additional thickening of the white. The results indicate that the process stabilizes the albumen against the thinning that ordinarily takes place in storage over a period of months.

Yolk Index

The yolk index *(11)* was determined by measuring the heights and the diameters of yolks of eggs broken upon a leveled glass plate. By dividing the height by the diameter, the yolk index was obtained. The results of this study are shown in Table 3.

TABLE 3

Index numbers of yolk in treated and untreated U. S. Grade A eggs as determined after specified periods of storage

Method of treatment	At beginning of storage	After storage for			
		1 mo.	4 mo.	5 mo.	8 mo.
No treatment (natural)	0.426	0.419	0.421	0.415	0.404
Oil processed	0.436	0.412	0.427	0.416	0.423
Stabilized:					
130° F. hot	.....	0.410	.....	0.382	0.391
130° F. cooled	0.416	0.406	.....	0.402	0.406
132° F. hot	.....	0.419	0.405	0.376	0.416
132° F. cooled	0.433	0.412	0.420	0.377	0.410
134° F. hot	.....	0.408	0.394	0.393	0.381
134° F. cooled	0.441	0.429	0.405	0.380	0.404
136° F. hot	.....	.....	0.377	.....	0.393
136° F. cooled	0.440	.....	0.383	.....	.....

The effect of heating may slightly improve the yolk index, although the differences in results shown here are not enough to be significant. There was a tendency for the yolk index to decline as the storage period increased, but a slight rise was noted between the fifth and eighth months. Paulhus *(9)* noted a similar increase after five months of storage and found certain indexes above those of the original readings. The reason for such findings is not known.

It was noted in opening eggs for index determinations, that more yolks were ruptured in the stabilized series than in either the natural or the processed series. There are not enough data to determine whether this observation has real significance.

pH Measurements

The pH measurements were made by means of a glass electrode, on thin whites and the yolks of eggs broken out for the thick- and thin-white studies.

No significant change in pH was noted, although the values in both the whites and the yolks were slightly lower in the stabilized series.

Whipping Quality of Albumen

Preliminary studies on the baking of cakes had indicated that thermostabilization altered the whipping quality of the whites. To determine to what degree this was true, a series of whipping tests was carried out by using the procedure of Slosberg and Stewart *(12)*. In these tests, after whipping under standardized conditions for 75 seconds, the specific gravity of the foam was taken as the relative whipping value of egg albumen. It was found that in many cases the albumen would not whip at all under the standard conditions but that if the time were markedly extended, a fairly good whip could be obtained. In certain cases nearly 5 minutes of whipping was necessary to obtain a specific gravity approaching that of "natural" eggs which had been whipped for only 75 seconds.

The study shows that the foam from stabilized whites, whipped the normal length of time, was heavy and not of good quality. Cakes baked from such whites were flat and of poor texture but the quality could be improved by extending the egg-whipping time. One explanation for this may be found in the whipping of the thick and thin portions of normal egg whites. A much heavier foam was obtained from the thick white even after extending the beating time more than threefold, and since a considerable quantity of abnormally thick white was found in stabilized eggs, this may account for the poor whipping quality.

Protection Against Weight Loss

Studies were made to determine the relative protection against weight or moisture loss by the various treatments. Examples will be found in Table 4. Treated

TABLE 4

Loss in weight of treated and untreated eggs stored under accelerated and normal conditions for stated periods

Temperature of storage	Time stored	Method of treatment	Average weight loss
			Percent
98.6° F. (37° C.)	20 days	Natural	19.0
		Oil-processed (85° F.)	7.4
		Stabilized (132° F.)	.9
		Stabilized (134° F.)	.9
30° F. (—1.1° C.)	5 months	Oil-processed (85° F.)	1.6
		Stabilized (130° F.) cooled	.8
		Stabilized (132° F.) hot	1.2
		Stabilized (132° F.) cooled	1.2
		Stabilized (134° F.) cooled	1.6

eggs were weighed and placed in a bacteriological incubator of 98.6° F. (37° C.) and held for 20 days. Another lot was placed in cold storage at 30° F. (—1.1° C.) and removed for weighing after 5 months.

The results shown are averages of weight loss of 18 eggs weighed to the nearest 0.01 gram at the beginning of the studies and at the end. The lack of agreement in the cold storage lot may be due to the wide variation

between individual eggs and the small amount of moisture loss . A marked moisture retention is shown by the stabilized eggs under the conditions of accelerated storage at 98.6° F. (37° C.). During storage at this temperature, embryonic development was noted in the "naturals" and oil-processed eggs, whereas no development was found in the stabilized eggs. This was in line with one of Funk's claims for the method *(4)*.

Quality Loss in Storage

Quality loss was determined by regrading the eggs after storage. This was done by the same grader that examined them at the beginning of the experiment. The cases of eggs were removed from cold storage and allowed to temper in a cool room until the eggs were at the same temperature as that of the initial grading. At intervals during the storage period representative cases were thus regraded. Such cases were not returned to storage, as it was believed that they would not represent true storage and handling conditions if used again. The change in the average percentage of U. S. Grade A eggs in the various lots is shown in Table 5. When placed in storage, all the eggs in the cases were U. S. Grade A or better.

TABLE 5

Average percentage of U. S. Grade A treated and untreated eggs retaining original grade after specified storage periods.

Method of treatment	Percentage of eggs grading U. S. Grade A after storage for			
	1 mo.	4 mo.	5 mo.	8 mo.
	Percent	*Percent*	*Percent*	*Percent*
No treatment (natural)	73	63	12	2
Oil processed	93	85	57	42
Stabilized:				
130° F. cooled	90	....	68	50
130° F. hot	89	....	69	51
132° F. cooled	....	91	67	60
132° F. hot	90	91	63	47
134° F. cooled	....	92	57	63
134° F. hot	....	91	49	61
135° F. hot	....	....	....	62
136° F. cooled	....	93	....	....
136° F. hot	....	92	....	47

It will be seen that the quality of the "naturals" declined rapidly and that oil processing markedly retarded this decline. After 4 months of storage, a superior quality retention is noted in the stabilized series. A lack of consistency in results is found with eggs stabilized at 134° F. (56.7° C.) and stored for 5 months. These eggs show a quality drop equal to that of the oil-processed eggs, yet this same series of eggs shows a superior quality retention at the 8-month period. The reason for this difference is not apparent in our records. Further study is under way upon which more conclusive results are expected.

The over-all results show that stabilized eggs retained quality to a higher degree than oil-processed eggs. A considerable shift from U. S. Grade A to U. S. Grade B was noted but very few U. S. Grade C eggs were found even after 8 months of storage, except in the natural eggs.

A question has been raised about the retention of quality in U. S. Grade B eggs by the stabilization process. To ascertain what quality retention could be obtained, a few cases of U. S. Grade B eggs were treated and placed in storage. The results after 8 months of storage are given in Table 6.

TABLE 6

Percentage of treated and untreated U. S. Grade B eggs falling into specified grades after 8 months of storage

Method of Treatment	Eggs grading U. S. Grade		
	B	C	Loss
	Percent	*Percent*	*Percent*
No treatment (natural)	47	50	3
Oil processed	77	17	6
Stabilized:			
130° F. cooled	82	14	4
132° F. cooled	87	9	4
134° F. hot	84	12	4
134° F. cooled	87	10	2

The stabilized eggs retained the grade to a better degree than did the oil-processed eggs. The amount of loss, however, was considerably higher than that found with the U. S. Grade A eggs.

Summary

1. The thermostabilization process markedly stabilized egg white against the normal deteriorative changes causing the thinning of egg white during storage.

2. Thermostabilized eggs retained their interior quality during storage to a better degree than "natural" or "oiled" eggs, as demonstrated by the candling procedure.

3. The percentage of thick white was greater in stabilized eggs than in "natural" or "oiled" eggs after 4, 5, and 8 months of storage.

4. Thermostabilization increased the albumen index, and it remained higher during all storage periods than the indexes of "natural" and "oiled" eggs.

5. The whipping properties of egg white were altered by the stabilization process. A marked increase in whipping time was necessary to obtain foam of a value comparable to that of untreated eggs.

6. There was less moisture or weight loss in the thermostabilized eggs than in the untreated eggs.

7. Thermostabilization had no marked influence on the yolk index. There was a slight increase in the index, but not enough to be of significance.

8. Thermostabilization brought about no significant change in the pH of either the white or the yolk of eggs.

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Preparation and Storage of Frozen Cooked Poultry and Vegetables[a]

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Some problems related to the retention of quality in various ingredients of frozen pre-cooked chicken a la king were investigated.

Expansion of the commercial precooked frozen foods industry depends on production of products of high initial quality and of good storage stability without undue expense. High quality comparable to that of the freshly prepared product is recognized as the main advantage of these foods over foods processed by methods requiring more drastic processing treatments. Methods of preservation requiring prolonged exposure to elevated temperatures result, of course, in products of greatly altered characteristics. Convenience is the advantage stressed when precooked foods are compared with foods frozen without cooking. All of the various ingredients required in a mixture such as chicken à la king are available in one container that merely requires heating rather than separate cooking and recombination of all items.

Many cooked foods have been frozen, and a few have presented distinct problems that are as yet unsolved. However, for most cooked items that can be more or less successfully frozen, there is a lack of specific information about the effect of the character of raw materials used, effect of various processing methods, and storage stability under varying conditions of packaging and temperature. The experiments reported here were designed to provide specific answers to questions on certain phases of the commercial preparation and storage of precooked frozen foods that have not received concentrated attention previously. They concern the effect of formulation variables, cooking methods, packaging, and storage temperature on the separate components of mixtures containing poultry, vegetables, and sauces. Such mixtures are typical of the products that are now of commercial interest.

Effect of Class and Breed on Flavor of Frozen Creamed Chicken

Precooked frozen foods are one outlet for surplus poultry of varying classes and grades, for malformed poultry of otherwise high quality, and for large turkeys. Since older birds can be made tender by appropriate cooking methods, and since malformations are of no importance in products where the meat is removed from the bone and diced before use, it should be possible to produce a frozen creamed chicken relatively inexpensively. An experiment was designed to determine whether a selected panel of judges could detect any differences that would indicate any possible advantage in using younger, more tender chickens rather than the older birds in a product such as frozen creamed chicken.

Chickens of high quality and approximately the same history were obtained in the following classes: Leghorn fowl, colored fowl, Leghorn rooster, colored rooster, and colored roaster. They were warm-eviscerated and held at 1.7° C. (35° F.) for 24 to 48 hours before cooking. The birds were simmered in covered containers with amounts of water proportionate to weight [1 liter (1.06 quarts) of water for each 2.27 kilos (5 pounds)]. Cooking times were varied as required to obtain cooked birds of approximately equal tenderness. Shear-force readings for representative thigh and breast muscles showed that all birds were cooked to approximately the same tenderness, since differences in tenderness among the five groups were statistically nonsignificant. The cooked birds were deboned, and the meat was diced, and frozen in sealed cans with a white sauce incorporating part of the cooking liquid. Light and dark meats were frozen separately.

The initial evaluation of flavor differences was begun as soon as the samples were frozen. A second analysis was made after the products were stored for six months at —23.3° C. (—10° F.). After thawing and reheating, the products were judged by a selected panel for differences in strength of characteristic flavor and degree of off-flavor among the five groups.

Statistical analysis of results showed only one consistent difference among the groups. That was the comparative lack of chicken flavor in creamed chicken prepared from roasters. The use of the older and less expensive birds is, therefore, not only permissible but under comparable conditions will yield a more flavorful product where tenderness can be controlled adequately by the cooking method.

Effect of Cooking Method on Flavor of Frozen Creamed Turkey

When older, less tender poultry is used, cooking methods such as simmering or pressure cooking are recommended, to make the product tender in a reasonable time without undue dehydration. When very tender poultry is available, the question arises as to a possible flavor advantage that might result with some

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[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. Report of a study made under the Research and Marketing Act of 1946.

other cooking method. Specifically, the question arose whether the desirable flavor associated with roast turkey might carry over into creamed frozen product, and thus whether roasting might be an advantage if quality of poultry permitted its use.

To obtain information on this point, Broad Breasted Bronze young tom turkeys were stuck, brained, slack-scalded, machine-picked, and chilled at 2.2° C. (36° F.) for 2-3 hours before evisceration. They were packaged in cellophane bags, frozen in a tunnel at —37° C. (—35° F.) and held at —34° C. (—30° F.) for 8 months. They were then sawed in half, thawed, and cooked by three methods: roasting in a 148.9° C. (300° F.) oven, simmering in a covered kettle [1 liter (1.06 quarts) of water per 2.25 kilos (5 pounds) of turkey], and pressure cooking at 12 to 15 p.s.i.g. Twenty-four half birds were divided among the three cooking procedures at random. After cooking, the birds were boned and the meat was diced, added to white sauce, and frozen in No. 1 short unlacquered cans at —23.3° C. (—10° F.) and stored at —17.8° C. (0° F.). For the first part of the experiment, designed to test any difference in the turkey *meat* resulting from the three cooking methods, the white sauce was prepared with a bland hydrogenated vegetable oil as the fat.

A second part of the experiment was designed to show any difference in flavor of creamed turkey when the rendered fat obtained by the three cooking methods was used in the white sauce.

For evaluation of flavor differences the products were thawed, heated, and presented to a selected panel of judges immediately after freezing and after various storage periods.

When the turkey meat alone was utilized, no significant differences were found in either strength of characteristic flavor or degree of off-flavor related to any of the cooking methods used, either at the original evaluation immediately after freezing or after 4 months' storage. When the three fat samples rendered during the cooking were used in the white sauce for the turkey, tests made immediately after preparation and after 3 and 6 months' storage showed that the samples containing fat rendered during the roasting process were significantly more rancid than either of the other samples. The results indicate that a considerable disadvantage results from acceleration in the development of fat rancidity during the roasting process if the fat is to be utilized in a creamed turkey product.

Since the experiment has shown an advantage for cooking turkey by a simmering method and because of the prevalence of suitable commercial equipment, the simmering method was selected for use in subsequent experiments.

Utilization of Turkey and Chicken Fat in Frozen Creamed Poultry

The question whether turkey and chicken can be used with equal success in precooked frozen mixtures was raised because of the surplus of large-sized turkeys. Since the relative instability of turkey fat compared to chicken fat is known to industry, it was believed that the utilization of poultry fat in the products might be the main condition that would limit the use of turkey. Therefore an experiment was designed to determine whether the turkey fat could be used as successfully in creamed frozen turkey as chicken fat could be used in creamed frozen chicken.

Broad-breasted bronze turkeys, 26 to 30 weeks of age, and New Hampshire yearling hens, both lots warm-eviscerated, were used in the experiment. The experiment was so designed that creamed turkey containing turkey fat in the sauce was compared with creamed turkey containing a hydrogenated vegetable oil in the sauce. The creamed chicken containing chicken fat was similarly compared with creamed chicken containing the hydrogenated vegetable oil. The birds were cooked by the method selected in the previous experiment, and the creamed products were packaged in a typical commercial container consisting of an MSAT cellophane bag, locker carton, and overwrap of laminated waxed paper. They were frozen in an air blast at —23.3° C. (—10° F.) and held at —12.2° C. (+10° F.) for evaluation after 4, 8, and 12 months' storage.

In Table 1 both the panel averages for off-flavor and the peroxide values indicate greater rancidity in the samples containing turkey fat than in the ones containing the hydrogenated vegetable oil.

TABLE 1

Effect of Fat Used in White Sauce on Rancidity of Creamed Poultry [c]

Storage time at —12.2° C. (+10° F.), months	Panel mean scores for off-flavor [d]			
	Type of fat in creamed turkey [c]		Type of fat in creamed chicken [c]	
	Turkey fat	Hydrogenated vegetable oil	Chicken fat	Hydrogenated vegetable oil
4	2.3	0.9	1.3	1.6
8	1.4	0.3	0.7	1.0
12	2.4	1.8	1.0	0.9
	Peroxide value (meq./kg.)			
4	15.7	8.0	1.9	1.9
8	15.2	7.7	6.1	4.5
12	16.2	8.4	2.4	2.7

[b] Packaged in MSAT cellophane bag and locker carton with laminated waxed paper overwrap.

[d] 0 = no off-flavor; 3 = slight off-flavor; 7 = decided off-flavor, and 10 = extreme off-flavor.

[c] Fat rendered during simmering of the poultry in covered containers.

The differences in off-flavor scores between the samples containing turkey fat and those containing vegetable oil were highly significant ($P = 0.01$) for the first two storage periods but not significant, although in the same direction, at the final period. The samples containing chicken fat, however, were not different from those containing the vegetable oil. Although there was no apparent increase in development of rancidity of the creamed turkey from the 4- to the 12-month storage period, the presence of detectable rancidity after 4 months' storage indicates that turkey cannot be used as advantageously as chicken in those products in which the poultry fat would be utilized. The application of antioxidants to permit the use of turkey fat is at present under investigation.

Effect of Storage Temperature and Container on Stability of Frozen Creamed Turkey, Chicken, and Peas

The relative storage stability of precooked frozen foods under varying conditions of temperature and packaging is of considerable commercial interest. In view of this fact, three representative creamed products were selected for study at temperatures ranging from —12.2 to —34° C. (+10 to —30° F.) and under two packaging conditions. One of these was a typical commercial container consisting of an MSAT cellophane bag in a locker carton with an overwrap of laminated waxed paper. The other container used was a No. 1 short unlacquered can, at present time limited to experimental work. The three products selected for study were creamed turkey, chicken, and peas.

Broad-breasted bronze turkeys, 26-30 weeks of age, and New Hampshire yearling hens were warm-eviscerated, pack-

aged in Cry-O-Vac, and frozen in an air blast at —40° C. (—40° F.). They were held frozen for approximately two weeks before processing. The birds were thawed overnight at room temperature and cooked by the simmering method. The birds were deboned and 70 grams of mixed light and dark meat were combined with 100 grams of white sauce, and frozen in an air blast at —23.3°C. (—10° F.). The liquid in the sauce consisted of half skimmed milk and half broth. Since previous experiments indicated that the inclusion of turkey fat would result in a rancid off-flavor under certain conditions, the white sauce for all products in this experiment was made with a hydrogenated vegetable oil. The experiment was so designed that the stored creamed turkey could be compared with samples prepared from freshly killed turkeys at the end of each of three storage periods, and the stored chicken could be similarly compared with freshly prepared chicken samples.

The peas used in the experiment were of uniform size (size 6), McFee No. 9 variety (Laxton's Progress type). They were obtained near Half Moon Bay, California. Pods were iced immediately after harvest and held at 1.7° C. (35° F.) until they were processed (20 to 25 hours later). Processing included mechanical podding and size grading, blanching, cooling, and freezing.

Portions of the graded material were placed on stainless-steel screen trays at a loading rate of 1.5 pounds per square foot and cooked for five minutes in a draper-type, belt steam blancher at 100° C. (212° F.). After cooking, the peas were cooled immediately for 2 minutes by a fog spray drawn through the loaded trays with the aid of a suction fan. They were combined with the white sauce in the proportion of 125 grams of peas and 50 grams of sauce and were then packaged or canned and frozen in an air blast at —23.3° C. (—10° F.).

The creamed chicken and creamed turkey were judged according to a balanced incomplete block design providing for 10 replications of each sample with three samples tasted at each judging period. Judging of the creamed peas followed a balanced incomplete block design providing for five replications of each sample and three samples judged at a time.

The off-flavor scores for the three products recorded in Table 2 show that when using cans, storage temperatures in the range applied had no effect on off-flavor development. However, under the other packaging condition the higher temperatures accelerated off-flavor development. The turkey samples held at —12.2° C. (+10° F.) in the package were significantly different (at the 1 percent level) from all other samples at every storage period. At the 8- and 12-month storage periods the samples at —23.3° C. (—10° F.) in the package were also significantly poorer than several samples of the other treatments. The creamed chicken held in the package at —12.2° C. (+10° F.) was significantly poorer than all other samples at all storage periods with the exception of the sample in the package at —23.3° C. (—10° F.) at the 8-month period. The peas held in the package at —12.2° C. (10° F.) and at —17.8° C. (0° F.) were significantly poorer than all other samples and significantly different from each other at both storage periods.

Whether the deterioration in flavor at the higher storage temperatures in the samples not stored in cans is related to development of rancidity, some other deteriorative change in the product, or absorption of off-flavors from the storage rooms or packaging material, has not been ascertained. In the case of the creamed turkey held 12 months at —12.2° C. (+10° F.) the judges commented that the off-flavor was rancidity.

Relative Storage Stability of Blanched and Cooked Frozen Peas

It has been reported that under certain conditions the frozen storage stability of cooked vegetables is not equal to that of adequately blanched vegetables *(1, 3, 4)*. The deterioration in flavor has been variously described as a "cooked" flavor and a "warmed over" flavor *(1, 3)*. Legault et al. *(2)* found little effect on the organoleptic quality of frozen peas with prolonged steam bleanching up to three times that required for an adequate blanch at 100° C. (212° F.) (as determined by test for peroxidase activity). It appeared possible that in the instances where the deterioration in flavor was reported in the cooked vegetables, there could have been an original difference between the cooked and blanched vegetables, not related to storage changes but rather to overcooking of the cooked samples. Therefore, an investigation was begun to determine the magnitude of the difference, if any, between the off-flavor development of cooked and blanched peas. Since cooked vegetables in a "solid" pack (surrounded by broth or sauce) were reported to retain their quality longer than those in a loose pack *(3)*, and since that is the condition in which they would be held in the usual precooked mixture, a comparison between a loose pack and a solid pack was included in the investigation.

The samples were prepared and stored in No. 1 short unlacquered cans at —17.8° C. (0° F.). The three treatments compared were (1) a blanched sample, (2) a cooked sample, (3) a cooked sample frozen in white sauce.

Three lots of peas were studied and the results on all lots are similar. The Wyola peas used were obtained from Patterson, California. They were vined in the field, iced, and transported to the laboratory where they were size-graded and

TABLE 2

Panel Means Showing Effect of Storage Conditions on Off-Flavor [c] Development in Precooked Frozen Foods

Product	Storage time, months	Storage conditions							
		MSAT cellophane bag, carton, laminated waxed-paper overwrap			No. 1 short unlacquered tin can				Fresh control
		—12.2° C. (+10° F.)	—17.8° C. (0° F.)	—23.3° C. (—10° F.)	—12.2° C. (+10° F.)	—17.8° C. (0° F.)	—23.3° C. (—10° F.)	—34° C. (—30° F.)	
Creamed turkey	4	1.9	....	1.3	1.2	....	1.2	1.3	1.2
	8	1.8	....	1.4	1.0	....	0.9	1.2	0.7
	12	2.4	....	1.5	1.3	....	1.1	1.0	0.8
Creamed chicken	4	1.4	....	1.0	1.1	....	1.0	1.0	1.0
	8	1.4	....	1.3	1.0	....	1.0	0.8	0.8
	12	1.9	....	0.9	0.8	....	0.9	0.9	1.0
Creamed peas	4	2.6	2.1	1.3	....	1.0	1.1	1.0	....
	8	3.7	3.2	2.6	....	2.3	2.2	2.4	....

[c] See footnote [4], Table 1, for meaning of scores.

processed on the day on which they were harvested. McFee No. 9 peas, sizes 3 to 6, were obtained from Half Moon Bay, Calif. They were iced in the field, hulled and sized at the laboratory and processed on the same day as harvested. The McFee No. 9 peas, sizes 7 to 8, were obtained from the same source but were held at 1.7° C. (35° F.) in the pods for 72 hours before hulling, sizing and processing.

The white sauce to be used in evaluation of the blanched and cooked samples that were frozen without sauce was prepared from the same lot as that for the solid-packed samples and stored separately in cans. At the end of the various storage periods the blanched peas were cooked, white sauce was added to the loose-packed samples, and both the blanched and cooked samples were heated in the white sauce on a steam table until they reached serving temperature (approximately 85° C. (185° F.). Preliminary studies were made to determine cooking and heating times required to give products of equivalent original color, flavor, and texture from all three treatments.

TABLE 3

Panel Mean Off-Flavor Scores[a] Showing Off-Flavor Development in Frozen Peas[b]

Variety	Size	Storage time at —17.8° C. (0° F.) (months)	Pre-freezing treatment		
			65-73-second blanch at 100° C. (212° F.)	5-minute cook at 100° C. (212° F.)	5-minute cook, solid pack
Wyola	2 to 5	0	1.0	0.9	0.9
		2	1.2	1.8	0.9
		4	1.6	2.3	1.8
		8	2.2	5.1	3.2
		12	2.5	5.6	2.5
McFee No.9	3 to 6	0	0.2	0.3	0.2
		2	1.1	1.5	0.9
		4	1.4	3.0	1.4
		8	1.9	4.8	1.5
		12	2.8	5.3	2.2
McFee No.9	7 to 8	0	1.6	1.8	1.8
		2	1.3	1.6	1.6
		4	1.7	2.4	1.8
		12	2.5	5.5	2.6

[a] See footnote [4], Table 1, for meaning of scores.
[b] White sauce added to cooked peas before freezing in No. 1 short unlacquered tin cans.

Table 3 shows that the cooked samples frozen and held in a loose pack deteriorated at a faster rate than samples of the other two treatments. The differences in off-flavor scores became statistically significant after two months' storage for the first two lots and after eight months for the third. Except for the first lot held for 8 months, the differences in off-flavor development between blanched and cooked samples held in a solid pack were not significant. No differences among the three treatments were found in either color or texture.

The results indicate that cooked peas do develop an off-flavor in storage at a faster rate than do blanched peas. Since there was no difference in degree of off-flavor at the original evaluation, the difference in flavor is not caused by overcooking of the peas before processing or during reheating. The cause of the difference in rate of off-flavor development has not been determined. The protective action of the solid pack has also not been explained except for the possible value of exclusion of air.

The results are encouraging in that with the use of a solid pack, the cooked frozen peas have storage stability similar to that of the blanched peas. However, these peas were stored in sealed cans, and it is possible that less favorable results might be obtained with different packaging materials.

Retention of Texture and Color of Cooked Frozen Vegetables

One frequent criticism of precooked frozen foods is that the vegetables have lost the crispness characteristic of fresh vegetables cooked to just the optimum stage of doneness. With careful control of processing conditions it is possible to produce precooked frozen vegetables of any desired degree of crispness. This can be accomplished by varying the cooking time before freezing and by rigid control of the reheating process. Where the conditions of reheating cannot be adequately controlled, the problem must be solved by selection of those vegetables that are not greatly affected by overheating or possibly by some pretreatment of the vegetable to prevent softening. Experiments to be reported here show that a few vegetables are only slightly affected by overheating but that most of those commonly used are adversely affected by only slightly prolonged periods of reheating.

One of the few vegetables that have shown resistance to change in texture on heating is the Chinese waterchestnut. Its texture does not change even under prolonged steam blanching at 100° C. (212° F.). Although the texture of most vegetables is affected by differences of one or two minutes in blanching time, the characteristic crisp texture of the raw waterchestnuts is still present after eight minutes of blanching. Freezing, thawing, and reheating do not change the texture. Since the waterchestnuts have a bland flavor, they may provide the desired crispness in a number of mixtures in which they are not now ordinarily used.

A number of the more common vegetables were studied to determine which of them were least susceptible to injury with slightly prolonged reheating periods and to determine the time of reheating which could be tolerated without damage to either color or texture.

All of the vegetables studied were cooked in a steam blancher at 100° C. (212° F.). The cooking time used for the different vegetables was intended to be slightly less than a complete cook, an amount such that after freezing, thawing, and a standard reheating period they would be at an optimum stage of doneness. Cooking in the steam blancher was followed by fog cooling for two minutes. The vegetables were then added to white sauce and frozen in circulating air in No. 1 short unlacquered cans at —23.3° C. (—10° F.). In preparation for judging, the frozen creamed vegetables were thawed for 1 hour in a water bath at 25° C. (77° F.). They were then transferred to covered beakers in a steam bath and heated with occasional stirring for periods from 25 to 40 minutes. The 25-minute heating had been found in preliminary tests to be sufficient to heat the vegetables to serving temperature [approximately 85° C. (185° F.)]. In all cases a comparison was made of the color and texture of the vegetables held on the steam bath for 25, 30, 35, and 40 minutes.

The results showed that of all of the vegetables tested the Golden Cross Bantam corn and the Kentucky Wonder beans were the only ones that were unaffected by the reheating periods tested. The lack of change in the beans was no doubt related to the fact that this particular lot of beans was rather mature and required a long period of cooking before freezing, during which the color change in the chlorophyll was pronounced. Further reheating did not alter this color and did not soften the rather firm texture.

In the case of peas there was some variation in response to reheating time, associated with variety and size of the peas. The crisp texture of the Wyola peas, sizes 2 to 5, and of the McFee No. 9 peas, sizes 7 to 8, was retained more successfully than that of the McFee No. 9 peas, sizes 3 to 6. In the two former lots a 15-minute difference in reheating time showed a significant difference in texture, while in the latter a 5-minute difference was significant. The Wyola peas, though small, naturally have a rather hard texture that withstands processing without much change. The large-size McFee peas were, of course, the more mature ones. All of the peas, however, showed a significant deterioration in color after an increase in heating of 5 minutes beyond the standard 25-minute period.

All of the other vegetables studied (snap beans, celery, carrots, lima beans, and peppers) showed significant deterioration in either color or texture or both after 5 or 10 minutes' reheating beyond the standard 25-minute period.

The results of this experiment have shown that the advantage obtained by selection of high-quality raw material and optimum conditions of processing and storage can be nullified by slightly prolonged periods of reheating on the steam table.

The comment has been made that precooked frozen vegetables do not withstand holding on the steam table as well as do the blanched frozen vegetables. In a limited experiment on one lot of peas, precooked and blanched frozen peas deteriorated in color and texture at the same rate when held on the steam table.

Conclusions

Older chickens of good quality can be successfully utilized in precooked frozen poultry products. Tenderness can be controlled by the cooking methods, and the older birds will yield a more flavorful product than younger birds.

The roasting method of cooking turkey for use in precooked frozen products has no advantage over other cooking methods in producing a product with a typical "roast turkey" flavor, and it has the disadvantage of accelerating development of fat rancidity.

Turkey cannot be substituted for chicken in precooked frozen poultry products if the poultry fat is utilized, without danger of a rancid off-flavor.

The type of package is of greater importance than storage temperature in the range from —12.2° to —23.3° C. (+10° to —10° F.) for retention of quality of precooked frozen creamed turkey and chicken. That is, with sealed cans the variation in temperature had no effect on development of off-flavor.

Cooked frozen peas held at —17.8° C. (0° F.) in cans develop an off-flavor in storage more rapidly than do blanched frozen peas. Cooked peas stored in a solid pack (surrounded by sauce) have approximately the same storage stability under these conditions as do the blanched peas.

Slightly prolonged periods of reheating frozen vegetables on a steam table will cause significant deterioration in color and texture and nullify the advantages obtained by the use of high quality raw material and optimum conditions of processing and storage.

Acknowledgment

We are indebted to Dr. F. E. Lindquist for advice and assistance in procuring and processing of the vegetables and to Iva S. Streeter for chemical analyses of the fat.

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Some Applications of Statistics to Laboratory Taste Testing[a]

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The application of a number of statistical methods to taste-testing data is described and charts are given for the rapid statistical evaluation of data.

Most food technologists are concerned sooner or later with the problem of flavor quality. There is a natural inclination on the part of both research and production technologists to consider their personal flavor preferences an adequate guide to product development or improvement. Often this self-confidence is justified by demonstrated success in developing products which are well accepted by the public. However, many so-called experts have not operated long enough or under such circumstances as to produce convincing proof of their reliability. The problem arises, in such cases, of estimating the risk incurred by accepting any given judgement of flavor quality.

The use of a group or panel of tasters permits one to estimate, in some degree at least, the limits of confidence to be placed in their flavor judgements. This is done by statistical analysis to determine the probability that a given judgement could have been reached by chance alone. Little statistical significance can be attached to most results from a panel numbering ten or fewer members. Also, confidence limits established in this way apply only to the particular panel employed, and imply nothing with respect to the panel's

[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

ability to reflect public opinion. The use of such panels to predict public acceptance is possible when durable standard samples are available to represent known degrees of flavor popularity. In some cases a judgement from a discriminating laboratory panel which reveals the presence of a rancid, moldy or fermented condition in a product which trade practice recognizes as foreign to that product, may be projected safely as a measure of general public reaction.

Panel Selection

Any method of selection should include a preliminary training period, designed to acquaint the tasters with the quality factors involved in the product to be tested. This should be followed by a blind test designed to show the individual's relative perception and discrimination. A workable procedure can be exemplified by the selection of a panel of coffee tasters. Three types of coffee brew known to differ in respect to some property, such as degree of roast, freshness, blend, etc., are presented in duplicate to each candidate under a random blind code. The taster is asked to arrange the six cups, by tasting, into three sets of pairs. There are fifteen possible paired combinations, only one of which is correct. A series of such tests, each involving some important characteristic of coffee flavor, is set up to extend over a period of twenty to thirty days, in order to make allowance for an occasional "off" day. At the end of this series the tasters are ranked in decreasing order of their successes in correct pairing. The top half is selected as a discriminating panel and the process repeated on a new group if necessary until a pool is developed from which at least fifteen people can be drawn at any one sitting for tasting coffee.

Other screening tests obviously can be designed, offering greater or less opportunity for chance success, depending on the degree of discrimination required from the panel.

Panel Tests to Establish Differences From a Standard

When it is desired to learn whether an experimental product differs from a standard in respect to a given quality, it is general practice to set up paired comparisons. The panel is asked which of two coded samples is the fresher, the more tender, or which has the more intense flavor, etc. To estimate the statistical significance of any given return from such a test, the chart shown in Figure 1 may be used. For example, if eight of a panel of ten tasters find sample A sweeter than sample B, the abcissa at 80 percent is read on the curve for panel size ten to show a "p" value on the ordinate equal to about 0.11. This means that such a panel judgement could be expected, on the average, eleven times out of one hundred tries by chance alone. It is not considered a good risk to accept any panel judgement as statistically significant unless the "p" value is less than 0.05, e.g., nine concurrences in a panel of ten; fifteen in twenty; sixty-one in one hundred, etc.

The "Triangular" Test

Frequently it is desired merely to learn whether a given sample differs at all from a standard, without regard to any specific quality factors. This can be

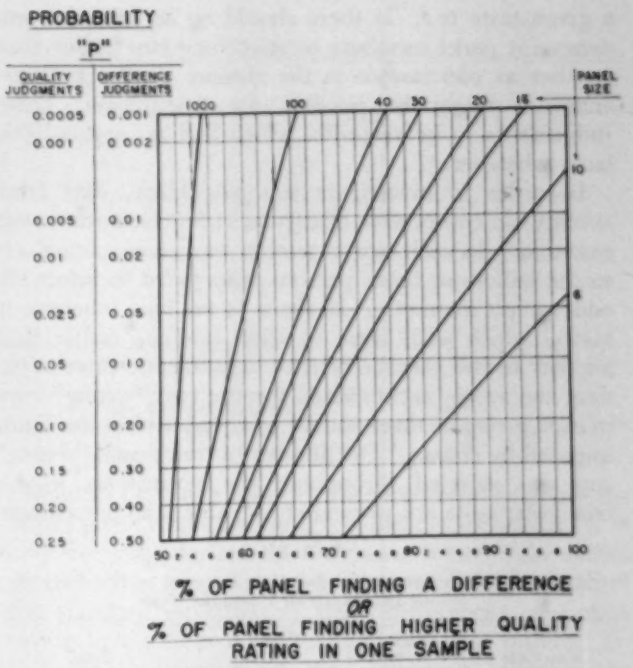

Fig. 1. Chart of Significance Levels (Paired Comparisons).

accomplished by presenting either the standard in duplicate plus the variant alone, or vice versa. In either case, the taster is asked to select the odd sample from the three presented *(1)*. Figure 2 shows diagrammatically the chi square analysis of this situation, just as Figure 1 does for the paired difference test. Figure 2 shows that only seven tasters in a panel of ten need to identify the odd sample correctly to achieve significance at the 0.05 level. This is obviously more efficient than the paired comparison test.

Psychological Hazards in Taste Testing

An unexpected difficulty which arose in the use of the triangular test on coffee samples may be used to illustrate an important point of procedure. Although the assignment of code letters was by random selection, it was the practice to code all sets of cups identically in

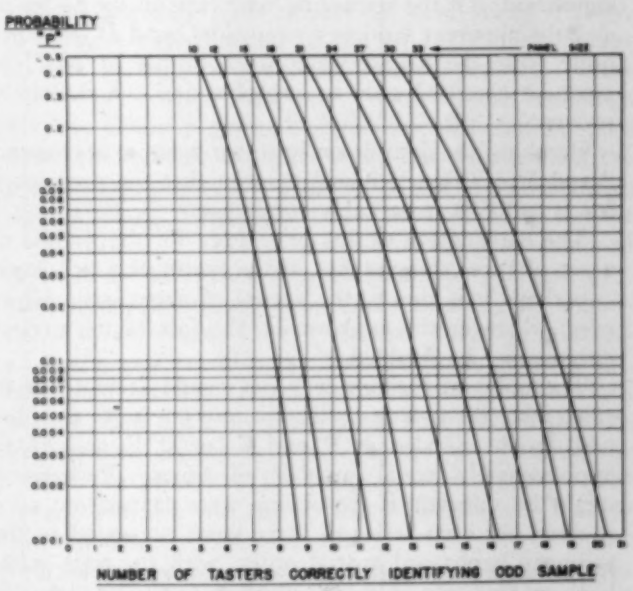

Fig. 2. Chart of Significance Levels (Triangular Test).

a given taste test. If there should be an inherent tendency for panel members to select one cup rather than another as odd sample in the absence of flavor differences, it might be possible for "significant" panel judgements to be recorded which had no organoleptic basis whatever.

In order to investigate this possibility, data from seventy-six consecutive triangular coffee taste tests were examined. In each case, attention was given exclusively to the ballots of those persons who *failed* to select the odd sample correctly. If there is no bias inherent in tasters which leads them to select one cup rather than another in the absence of true organoleptic discrimination, the scores accumulated for the two "wrong" cups in each group of three should be equal, within the limits imposed by chance. The number of times each "wrong" cup was selected throughout the seventy-six double triangular tests are presented in Table 1 as percentages

TABLE 1

Effect of Spatial Arrangement and Code Lettering on Frequency of Wrong Judgements in Triangular Tests

Cup Code	Period I 11/8/48-12/30/48	Period II 1/3/49-1/28/49	Total
A	43.8 percent	48.5 percent	45.2 percent (n=221)
B	60.7 percent	60.7 percent	60.7 percent (n=293)
C	43.8 percent	41.9 percent	42.9 percent (n=298)
D	43.9 percent	39.6 percent	42.2 percent (n=258)
E	58.9 percent	61.0 percent	59.5 percent (n=309)
F	44.3 percent	50.0 percent	46.1 percent (n=253)

of the total "wrong scores," (n). The results for the 1948 portion of the data and the 1949 portion are first presented separately, then the overall results are shown.

It appears that B and E definitely tend to be preferred, while A, C, D, and F are avoided.

Examining these results statistically, we find that the preferences for B and E are proved to odds of about 670:1 and 330:1 respectively. If it is justifiable to combine these two, then the overall odds to which the preference for the selection of the middle as the odd cup in any series of three is proved, rises to approximately 10^6:1. Either way, the results are comfortably significant. Of the remaining four cups in the series of six, the apparent tendency to avoid C and D does not quite clear the lowest significance hurdle of 20:1, so must be accepted only as probable and not definitely proven.

Breaking the data down into two groups, in columns 2 and 3 of Table 1, it will be seen that the preference for B and E is remarkably consistent.

The explanation of this preference for the middle of a set of three samples lies in the realm of psychology, —perhaps it is due to the appeal of symmetry. However, whatever the explanation, the fact of the preference cannot be doubted.

The only satisfactory way out would seem to be to randomize the coding so that in any one taste test, the odd sample is coded A, B, and C (or D, E, and F) an approximately equal number of times. Perhaps it might be sufficient if the coding were carried out as it is now, but each series of three were presented to the taster in haphazard spatial order, with the code numbers on that side of each cup *away* from the taster so that he cannot see them. After making his judgements he could then turn the cups around to discover the code letters.

Numerical Scoring

When it is desired to compare more than two samples for some flavor quality, much time can be saved by presenting as many as four variants, together with a standard, for relative numerical scoring, usually on a one to ten scale. We have found it essential to present the standard in duplicate,—one an "open" standard to which an arbitrary score value is assigned,—the other a "blind" standard. The blind standard will almost always receive a slightly different score than that assigned to the open standard. Mean scores for the panel are calculated for each blind coded sample. In order to test the significance of the difference between a variant mean (m_x) and the (blind coded) standard mean (m_y), the most usual technique is to calculate the standard error of the difference:

$$\sigma_{(m_x - m_y)} = \sqrt{\frac{\sigma_x^2 + \sigma_y^2}{N}} \qquad (1)$$

where σ_x and σ_y are the standard deviations of the scores to be compared and N is the number of tasters. If the difference observed between the two means is greater than (say) twice this value, then it is regarded as significant. Where the number of tasters is small, the t-test small-sample modification of the method would be used.

Actually however, this formula is incomplete, and should read:

$$\sigma_{(m_x - m_y)} = \sqrt{\frac{\sigma_x^2 + \sigma_y^2 - 2r\sigma_x\sigma_y}{N}} \qquad (2)$$

where r is the coefficient of correlation between the scores *(4)*. The (fictitious) examples in Table 2 will illustrate this point.

The correlation coefficient has been worked out between the pair of samples for each taste test. The values found are shown in Table 2. As inspection will show, the only difference between the results of taste test 1 and 2 is due to the performance of three tasters K, L, and M in test 2 who replaced tasters, A, D, and H in test 1. Tasters K, L, and M evidently show about the same *discrimination* as the persons they replace,—indeed the difference between the means of the two samples remains the same in test 2. They differ, however, in their attitude to the samples in general, assigning their quality to a lower plane than the other judges. It is this latter fact which evidently must account for the higher value of the correlation coefficient in test 2. We may say, then, that a high correlation between taste scores of two samples may be interpreted as meaning that the variation among the different tasters in their perception of a given taste stimulus is large compared with their judgement of the difference between the two samples. From formula (2) it is evident that the larger the value of the correlation coefficient, the smaller becomes the standard error by which the significance of the difference between the two mean scores is assessed. That is to say that in all cases except those where the correlation coefficient works out to be zero or negative (which will be a rare event) the

TABLE 2

Data Illustrating the Effect of Correlation on the Estimate of Standard Error

Taster	Taste Test 1			Taster	Taste Test 2		
	Variant A	Variant B	A-B		Variant A	Variant B	A-B
A	8	7	+1	K	4	3	+1
B	7	6	+1	B	7	6	+1
C	7	7	0	C	7	7	0
D	9	8	+1	L	3	2	+1
E	8	8	0	E	8	8	0
F	8	6	+2	F	8	6	+2
G	8	7	+1	G	8	7	+1
H	7	7	0	M	2	2	0
I	7	8	−1	I	7	8	−1
J	7	6	+1	J	7	6	+1
Total	76	70	+6	Total	61	55	+6
Mean	7.6	7.0	+0.6	Mean	6.1	5.5	+0.6
Correlation Coefficient:			+0.435	Correlation Coefficient:			+0.930
Standard Error: Formula (1):			0.375	Standard Error: Formula (1):			1.065
Formula (2):			0.282	Formula (2):			0.282

standard error as calculated by formula (1) will yield too high a value so that the sensitivity of the test will be thereby reduced. It must be remembered, however, in using the t-table that the degrees of freedom for this procedure are n-1 as against 2n-2 for the formula using the standard error of the difference between two means which ignores the correlation.

In the case of the two tests here instanced, we get the values shown in Table 2 for the standard error using formulae (1) and (2), respectively.

It is seen that the reduction in the standard error brought about by using formula (2) instead of formula (1) is appreciable in taste test 1 and very considerable in taste test 2. The full force of this may be brought home when it is appreciated that in the case of taste test 1, the use of formula (1) would require a panel of about 1¾ times the size to obtain a standard error and critical ratio of the same size as that obtained by using formula (2) with the present panel. For taste test 2, the panel would have to be about fourteen times the size.

Simplification of Calculation

The normal formula employed for the calculation of the correlation coefficient is—

$$r = \frac{\Sigma (x - \bar{x})(y - \bar{y})}{\sigma_x \sigma_y N}$$

In our case x and y are the individual scores, $\bar{x}$ and $\bar{y}$ the mean scores given to the two samples and σ_x and σ_y their standard deviations. N is the number of tasters participating in the test.

It can be shown, however, that the following alternative formula is algebraically identical with that given above *(4)*.

$$r = \frac{\sigma_x^2 + \sigma_y^2 - \sigma_d^2}{2\sigma_x \sigma_y}$$

where σ_x, σ_y are as before and σ_d is the standard deviation of the *differences* between the scores of the two samples allotted by the various tasters.

Substituting this formula for r in formula (2), we get

$$\sigma_{(m_x - m_y)} = \sqrt{\frac{\sigma_d^2}{N}} \qquad (3)$$

It therefore transpires that the calculation of the true standard error of the difference between means is actually simpler than that of the inflated value given by formula (1) which ignores the correlation between the scores given to the two samples under comparison. It is only necessary to find the difference between the scores given to the two samples by the various tasters, find the standard deviation of these differences, and then divide by the square root of the number of tasters. To test the significance of the difference between the means, it is only necessary to divide this by the standard error so obtained; this will give the critical ratio. Where the number of tasters is small, it is safer to interpret the critical ratio against the t-tables.

A numerical scale for scoring often proves to be a "rubber yardstick" unless the precaution is taken to include more than one fixed standard at predetermined points on the scale for the orientation of the taster. Repeatedly we have observed that a wide average score difference, observed between two samples when presented by themselves, will shrink when a third higher quality sample is presented along with them. This phenomenon is familiar to the psychologist who recognizes it as "adaptation."

Ranking

A procedure that is widely used when more than two products are to be rated involves arranging them in ordinal sequence with respect to some stated quality. The highest rated sample is ranked 1, the next highest 2, etc., so that the numerical ranking tends to follow numerical scoring inversely. Panel mean rankings tend to follow a normal probability distribution, provided the number of tasters is not less than ten and the number of samples being ranked is not less than three. The ordinary "t-test," therefore, can be used to test for significance. This involves estimating the standard error of the difference between means by equation (1), calculating the critical ratio and estimating its significance by reference to the "t"-tables. Actually, valid use of the "t-test" requires that further assumptions be fulfilled and for this reason, professional mathematicians do not look with favor upon applying the "t-test" to ranked data. However, psychologists have justified the use of the procedure by the pragmatic argument that long experience has shown that it works well enough in practice.

Ranking tests are generally less efficient than numerical scoring for small laboratory panels. This is due to the fact that ranking disregards degrees of difference.

On the other hand, ranking may be useful in assessing the mean preference of a consumer group which has not been screened to eliminate "perverted" tasters, i.e., those who may have strongly divergent opinions as to the acceptability of certain flavors. For example, suppose four samples are being scored for some quality factor on a zero to ten rating scale by a panel of ten persons who, on the average, rate the samples around six to eight points. Then one "perverted" taster who decides to award a zero to one sample he dislikes intensely would reduce the mean score of that sample by almost one point. If, instead, the samples had been ranked by the panel, the "perverted" taster would be restricted in the extent to which he could show his disapproval,—i.e., he could only place the disliked sample in the bottom ranking position. This would represent a much smaller departure from the mean score (in terms of standard deviation) than in the first case where ratings were used.

Generally speaking, laboratory panels should be used for difference testing rather than acceptance testing. When it is necessary to request a preference judgement, ranking scores may be the best to use.

Sequential Methods

It is a well-known fact in the field of quality control that sequential sampling reduces the amount of sampling required by, on the average, a factor of about two. This principle may be applied to taste testing procedures in which it is required to investigate, for example, which of two coded samples of coffee tastes fresher. The samples are first presented to a small panel; if the opinions are sufficiently in favor of one of the samples (determined statistically as described above), then further testing will be quite unnecessary. However, if the result of this small test is not decisive then a supplementary test is run and the results amalgamated with the first test, and the statistical significance of the combined result redetermined. This may be repeated for a third time, if necessary *(6)*.

Threshold Tests

The concentration of a particular flavor (or odor) which can just be detected 50 percent of the time, on the average, is known as the threshold concentration *(2)*. In addition to its usefulness in evaluating the appearance of "off" flavors, the threshold test is potentially useful in estimating flavor differences by the method of mixtures. It can also be used for scoring specific flavor qualities in a natural mixture against a graded series of controls, such as dilutions of sugar or salt in water.

In order to retain the advantages of blind coding, we prefer to use a method which presents the taster with a series of paired samples randomly arranged. Each pair contains one dilution of the flavor under investigation and one blank. The blank may be water or any desired combination of flavors other than the one being tested. The taster is asked to identify the sample containing the test flavor. For example, a series of dilutions of $CaCl_2$ in water or in 1 percent salt brine may be compared with an equal number of blanks consisting of water or brine, respectively.

With a test set up in this way, we should expect on the average to get 50 percent correct identifications by chance alone. Therefore, the threshold will be the concentration correctly identified by 75 percent of the panel. It is convenient to convert the percent (p) correct identification at each level to a "percent above chance," which is expressed as $2(p-50)$.

Figure 3 shows the results of a threshold test in which the concentrations vs. percent-above-chance

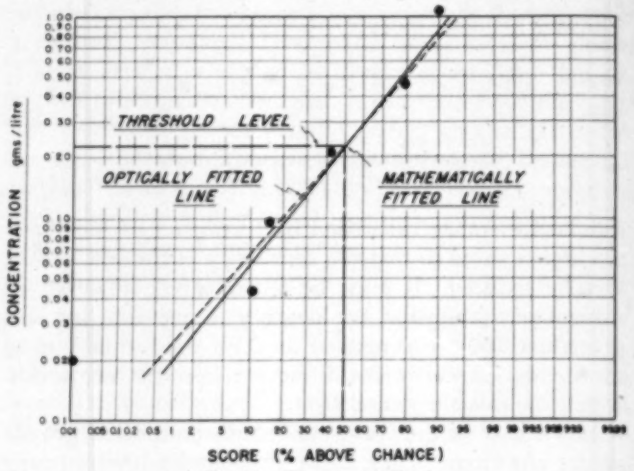

FIG. 3. Threshold Test.

scores are plotted on log-probability paper. This choice of coordinates is taken because flavor perception is expected to vary with the logarithm of the stimulus value (Weber-Fechner Law) and the distribution of scores around the halfway point is assumed to follow the normal probability function. The best-fitted straight line can be used to read an estimate of the threshold value from its intersection with the 50 percent-above-chance score. A more precise estimate of the threshold can be obtained by mathematical line-fitting, in the course of which confidence limits may also be determined. It is often difficult to give a threshold any useful interpretation unless the confidence limits are also known.

Control Chart Methods

A convenient method for showing confidence limits in numerical taste test scores is provided by the Shewhart "control chart." This is a graphical method of presenting data which makes use of tables for estimating standard errors from small sub-groups of data *(5)*. It is particularly useful for showing when individual panel members are "out of control" with respect to the panel average, or other criterion of reliability *(3)*. Since much has been published concerning this method, particularly with reference to quality control, it will not be necessary to present further details in this paper.

Summary

A number of applications of statistics to taste-testing are discussed. A panel selection procedure is described. Where scores are alloted to samples, a statistical treatment which allows for correlation between scores is shown to give a more sensitive analysis of the data. Attention is drawn to psychological hazards which were discovered in the triangular type of taste-test. Charts are offered to simplify the statistical evaluation of taste-

test results. The possibility of using sequential methods and the use of logarithm-probability paper for the solution of threshold-problems are briefly discussed.

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The Problem of Chocolate Bloom[a]

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The "blooming" or "graying" of the surface of chocolate candy is an important and intricate problem. The reasons for the occurrence of this type of deterioration and the various ways of avoiding it are discussed in view of recent results obtained in research work conducted at Lehigh University and elsewhere.

The thin coating or scattered patches of white or grayish material which sometimes develops on the surface of chocolate candy is commonly referred to as a "bloom" while the deterioration is known as "blooming" or "graying." The formation of this bloom renders the product unsalable due to its unattractive appearance. This lightening in color and crumbly structure may in fact extend through the thickness of the piece or coating, producing a very unpalatable texture.

Two distinct types of bloom are recognized and are distinguished as (a) "sugar bloom" and (b) "fat bloom." The sugar bloom is characterized by a sandy or gritty feel and consists of crystals of relatively high melting point which may be identified as sucrose. The development of sugar bloom is attributed to one or a combination of the following conditions:

1. A high moisture content or a high humidity accompanied by variations in temperature resulting in the deposition of condensed moisture on the chocolate surface ("freak moisture").
2. A low percentage of fat in the chocolate.
3. The use of a low-melting fat in chocolate coating of moist centers.
4. The use of a very fine sugar in the chocolate.

This type of bloom can usually be prevented by proper control of moisture, careful handling and storage, and the use of at least 34 percent of fat in the chocolate mass.

The characteristic tendency of chocolate candy or coatings to develop fat bloom under adverse conditions has been a major problem in the confectionery industry for many years. Research sponsored by the Pennsylvania Manufacturing Confectioners' Association at Lehigh University for the past several years has included as a principal objective the determination of the nature of fat bloom, the mechanism by which it occurs, and possible means of controlling it.

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

Fat bloom is characterized by a greasy feel; the light-colored material which appears on the surface consists of crystals of low melting point. This type of bloom is usually caused by exposure of the product to rather wide variations in temperature, but may occur on long storage at moderate temperature. The relative tendency of any chocolate product to bloom is highly dependent upon the previous treatment of that chocolate mixture with respect to temperature, time, and agitation.

The Structure of Chocolate

Melted chocolate consists of a dispersion or fine suspension of solid particles (cocoa solids) in a continuous medium of liquid fat (cocoa butter). When this fluid mass is cooled it sets or freezes to a brittle solid by the solidification and some degree of crystallization of the cocoa butter medium. That is, the system changes physically from a dispersion of a solid in a liquid to a dispersion of a solid in a solid medium (solidified cocoa butter). Thus the actual surface of solidified chocolate is a continuous film of pure cocoa butter and the appearance, glossy or bloomed, of the chocolate product depends primarily upon the nature and physical structure of this surface film of fat. Any investigation of the phenomena associated with the solidification of chocolate, including the subsequent development of bloom, will therefore focus upon the physical behavior of cocoa butter in relation to the conditions of its treatment. However, it should not be overlooked that the fineness and degree of dispersion of the solid phase (the cocoa solids) can influence the behavior of the continuous phase and therefore affect the stability of the whole system.

That the fat bloom of chocolate is strictly a physical phenomenon, involving no chemical change in the components of the system, is attested by the fact that a badly bloomed chocolate can be reconditioned to a satisfactory product by remelting and properly tempering the bloomed material.

It is generally agreed that in order to produce a chocolate candy or coating which will be resistant to blooming or will stand up well at higher temperatures it is necessary to accomplish essentially complete crystallization of the cocoa butter. This natural fat is a complex of mixed glycerides of the fatty acids, oleic, palmitic and stearic. It is very difficult to separate cocoa butter

into its pure components; each contributes to lowering the melting point of the mixture and interferes with the crystallization of the other components.

It has been shown by calorimetric measurements in a series of tests that 85 percent of the crystallizable fat must be crystallized in order to obtain a chocolate product with a lasting gloss. The remaining fat was found to crystallize if the finished product was stored at a temperature of 68° F. or lower, but at least 24 hours are required to complete this process *(1)*. It is therefore recommended that finished chocolate goods be held at 70° F.(21.1° C.) or a lower temperature for at least one week before shipment, to insure complete crystallization of the fat and hence maximum resistance to subsequent changes on exposure to higher temperatures.

Segregation of Fat in Bloom

The crystallization of cocoa butter and the related stabilization of chocolate is further complicated by the fact that the fats involved here are able to crystallize in several, perhaps four, different crystal forms. Only one of these forms is stable at ordinary temperatures and therefore fat which has solidified in any of the other forms will eventually revert to this stable form. This transformation from a less stable to the more stable crystal form always occurs with the evolution of heat and this latent heat may contribute to the melting of some of the lower-melting and less stable crystals in the mixture. Crystals of higher melting point will have the best chance to survive and will be to some extent pushed to the outside of the chocolate piece or coating by the liquid fat which expands as it melts. The higher-melting component is soluble in the low-melting fraction, especially at higher temperatures, and this dissolved material will deposit on the remaining crystals of the higher-melting component at the surface as the mass cools. The melted portion of the fat will also crystallize and contract upon cooling and the last remaining liquid will perhaps be drawn back into the porous solid mass leaving the bloom above the surface of the chocolate.

The process just described explains the partial segregation of fat from cocoa solids to produce a granular crumbly structure in a poorly tempered chocolate or in chocolate which has been exposed to excessively high temperature and then cooled. This mechanism also accounts for our observation that the surface bloom contains a fat of higher melting point than that of the cocoa butter in its composition. The data in Table 1 support the conclusion that the bloom contains a higher-melting fat since melting point is inversely related to iodine number:

To substantiate this relationship further, a standard cocoa butter having a melting point of 85.0° F. (29.4° C.) was separated into 8 fractions. The highest-melting fraction 91.0° F (32.8° C.) was found to have an iodine number of 34.9.

TABLE 1

Iodine Numbers of Cocoa Butter and Bloom

Sample	Iodine No.
Standard No. 1	39.83
Standard No. 2	38.40
Bloom from No. 1	34.77
Bloom from No. 2	33.69

X-ray Evidence of Fat Crystallization

X-ray diffraction studies, performed here with the assistance of Professor H. V. Anderson, have indicated that the bloom removed from the surface of chocolate is definitely crystalline in structure. A comparison of x-ray diffraction patterns of (a) cocoa butter which had been melted and chilled rapidly and (b) cocoa butter which had been melted and then carried through a proper tempering procedure clearly showed that the tempered fat had a more definite and complete crystallinity.

Control of Bloom by Tempering

As implied in the foregoing discussion, the most important means of protecting chocolate products against bloom is the proper handling of the chocolate mass. This includes correct tempering and subsequent storage under controlled conditions. The process of tempering has been variously defined as the removal of latent heat; the formation of a proper "mush"; the production of a chocolate having a good color, a glossy and enduring surface, and a texture which results in a definite "snap" when broken. Our experiments indicate that tempering involves the establishment of a structure in the cocoa butter involving a sufficiently high percentage of fat crystals of the stable type.

Several methods of tempering chocolate are practiced in various plants. One method consists in rapidly cooling the chocolate to 86° F. (30.0° C.) and then raising the temperature several degrees to the coating temperature. In this process the rapid chilling will produce many seed crystals and the subsequent elevation of temperature will melt the less stable forms, permitting those of the desired stable type to remain as seed crystals for proper solidification of the chocolate when it is poured or used in coatings. A different tempering process involves the very slow cooling of the chocolate over a period of 24 hours from melt temperature to the desired coating temperature. A third process is continuous tempering. In any process of tempering a suitable amount of agitation of the chocolate mass is essential to a satisfactory product.

In a systematic study of tempering conditions we have found that for any temperature in the range used there is a minimum time required to develop a stable system. As shown in Table 2, chocolate can be tempered by holding it for 150 minutes at 86° F. (30° C.) but at least 225 minutes are required at 87.8° F. (31° C.).

TABLE 2

Minimum Times Required for Tempering at Various Holding Temperatures

Holding temperature	Minimum time required
84.2° F. (29° C.)	120 minutes
86.0° F. (30° C.)	150 minutes
87.8° F. (31° C.)	225 minutes
89.6° F. (32° C.)	360 minutes

After a well-tempered chocolate has been produced, it can be maintained and stabilized further only by storage under proper conditions, usually involving refrigeration. Repeated heating to moderate temperatures or exposure to excessive heat will adversely affect the stability of the system and produce fat bloom.

Modification of Chocolate

Since the production of well-tempered chocolate does not prevent fat bloom at the higher temperatures to which chocolate products must sometimes be exposed, we have sought some modification of the system which will overcome this limitation. Two general methods are being followed toward this objective. One method involves the addition of various chemical modifiers such as surface-active agents, emulsifiers, and stabilizers.

Results of these studies indicate that if a proper tempering procedure is followed, certain additives increase the stability of the system, reducing the tendency of the chocolate to bloom when subjected to unfavorable conditions. While not many products have yet been fully tested, the most effective additive for this purpose which we have found so far is Span 60, or an equal mixture of Span 60 and Tween 60,[b] at a concentration of approximately one percent in the chocolate mass. These agents are added and mixed in remelting the chocolate. It must be emphasized that in order to obtain any beneficial results from such additives it is still necessary to observe the proper time-temperature relationships in tempering the chocolate. A slightly longer time of tempering is required at a given temperature if the additive thins the chocolate, and a shorter time may suffice if the additive has a thickening effect.

The alternative method of attack in progress is the modification of the cocoa fat, or a portion of it, by hydrogenation, fractionation, or isomerization. Our experiments indicate that a chocolate of greatly enhanced bloom resistance may be produced by the use of a modified fat. However, any modification of the fat necessitates an appropriate change in the tempering conditions in order to accomplish the desired improvement. Studies of the tempering of modified fats are being conducted.

[b] Both derivatives of sorbitol, manufactured by the Atlas Powder Co. of Wilmington, Delaware.

Accelerated Tests for Stability

As a means of predicting the stability or shelf-life of chocolate products prepared under various conditions several test methods are employed. The simplest of these is storage at ambient room conditions with periodic examination. A second procedure comprises of holding the chocolate products in heating cabinets at a constant temperature of 90° F. (32.2° C.) for progressively longer periods of times as 24, 48, or 72 hours, followed by a cooling at room temperature for 24 hours before test observations are made. A third method involves a series of heating cabinet tests at progressively higher temperature steps from 88° to 98° F. (31.1° to 36.7° C.) for periods of 2, 4, and 7 days. These samples are also cooled at room temperature for 24 hours before making observations upon them.

In an effort to accelerate testing procedures and to obtain quantitative data for comparison we have been using a sensitive penetrometer as one means of evaluating the condition of the chocolate. In general, a well-tempered chocolate will show a greater resistance to penetration.

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The Role of Enzymes in Milling and Baking Technology[a]

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A REVIEW

The occurrence of some enzymes in cereal grains and the role of enzymes in milling and baking technology are discussed.

Introduction

Many enzymes play a significant role in the behavior of wheat and wheat products during processing but the present review of the current status of our knowledge concerning them will be confined to the amylases, lipase and lipoxidase. The enzymes involved in yeast fermentation and a consideration of the possible role of proteases in breadmaking are omitted since an adequate treatment of these topics is beyond the scope of a brief review.

Amylases

In breadmaking, the amylase activity must be maintained within certain limits to obtain optimum bread. Sound wheats contain relatively large amounts of beta-amylase whereas their content of alpha-amylase is extremely low. Much of the beta-amylase is present in an inactive or "bound" condition which is liberated and becomes active, or "free," when the grain is germinated; concurrently there is a marked increase in alpha-amylase activity. Digestion of an aqueous suspension of ground ungerminated wheat with proteolytic enzymes also results in the liberation of free beta-amylase but has relatively little effect on its alpha-amylase activity *(14)*.

Importance of Alpha-Amylase in Breadmaking

The mode of action of the two amylases is of great importance in breadmaking. Beta-amylase, the acid-stable, thermolabile, saccharifying enzyme, is unable to attack raw, mechanically-uninjured starch and hydrolyzes damaged starch slowly. In contrast, alpha-amylase, the acid-labile, relatively thermostable dextrinifying component of malted wheat and barley attacks damaged starch much more vigorously than beta-amylase and it, or an enzyme associated with it, is capable of attacking starch which is not sufficiently

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damaged to be susceptible to beta-amylase. In view of these differences in their properties, and the fact that sound wheat flours contain relatively large amounts of beta-amylase, alpha-amylase is the component which is of the greatest significance in production control in breadmaking. An adequate level of alpha-amylase activity is essential for the maintenance of a sufficiently high rate of gas production to leaven the dough and also to provide a residue of sugar to yield bread with a desirable taste and crust color. Moreover, important changes influencing the quality of the bread occur as a result of starch degradation by alpha-amylase during oven baking, the extent of which depends upon the enzyme concentration, the rate at which the temperature of the dough rises, the hydrogen-ion activity of the dough and the concentration of calcium ions.

For several minutes during the early part of the baking process, conditions are favorable for the rapid attack of starch by alpha-amylase. For example, it has been found that the interior temperature of 500-gm. loaves baked at 392° F. (200° C.) reaches 140° F. (60° C.) in about ten minutes and requires an additional two to three minutes to attain a temperature of 158° F. (70° C.). The pH of bread doughs is normally between 5.0 and 5.6 at the end of the proof period, and as calcium ions (which stabilize alpha-amylase but have an inactivating effect on beta-amylase activity) are present, alpha-amylase activity is quite pronounced. Wheat starch begins to gelatinize at a temperature of 149 to 154° F. (65 to 68° C.) and this is accompanied by a marked increase in its amyloclastic susceptibility. The liquefying effect of alpha-amylase, together with the increase in the temperature of the dough, decreases its consistency and, within desirable limits, this assists in obtaining a maximum "oven-spring," or increase in volume in the oven. As the temperature continues to rise, progressive heat-denaturation of the gluten occurs with a consequent decrease in its imbibitional capacity; on the other hand the starch swells and undergoes a partial gelatinization, which is limited by the amount of available water. Dextrinization of a portion of the starch lowers its hydration capacity so that the water set free by heat-denaturation of the gluten proteins is not so firmly bound and this results in bread which seems more moist and has a softer crumb. Excessive liquefaction and dextrinization of starch during oven baking are considered to be responsible for a loaf of poor symmetry, with a moist dough-like crumb of poor eating quality. The correct level of alpha-amylase activity is of particular importance in the manufacture of breads made largely or entirely from rye flours; insufficient alpha-amylase activity is characterized by a dry, brittle crumb, while an excess results in bread with a soggy, dough-like crumb which often pulls away from the crust leaving large hollow spaces *(7, 29)*. Excess alpha-amylase activity is of particular significance in bread doughs that are baked slowly *(21)*.

Thus, alpha-amylase activity is important in breadmaking during both fermentation and oven baking, and must be maintained within certain limits if optimum bread is to be obtained. It has been clearly demonstrated that normal flours contain sufficient quantities of beta-amylase and that an increase in this component does not have any material influence on dough or bread properties whereas small quantities of alpha-amylase normally have very marked effects *(23, 38)*.

In the United States and Canada, the bread wheats produced in the Great Plains area are usually harvested under dry weather conditions and, unless special precautions are taken to provide sufficient sugar in the baking formula or to add an amylase supplement, baking failures may result because of inadequate gas production. It is not surprising, therefore, that milling and baking technologists in America first concerned themselves with the development of methods which would serve as an index of the ability of the flour to support yeast fermentation and to employ them in controlling the addition of malted wheat flour or malted barley flour. During the past few years higher rates of supplementation with these sources of alpha-amylase are commonly used than are necessary for optimum sugar levels, the object being to secure more extensive modification of the starch during baking *(35)*. This shift in emphasis has had a considerable influence on the methods employed in production control.

Measurement of Amylase Activity of Wheat Flours

Autolytic procedures have long been used in wheat flour technology to secure a measure of amylase activity under conditions which approximate those encountered in dough. These methods measure the summation of several factors such as enzyme concentration, substrate susceptibility, and any other variables which may be operative, so that they give an integrated result of practical utility. Saccharogenic activity is measured by the so-called diastatic activity, or "maltose value" determination, based on the work of Rumsey in 1922. In this method the reducing sugars, expressed as mg. maltose per 10 grams of flour, are determined after autolyzing an aqueous flour dispersion (flour-water rattio 1:10) at pH 4.7 for one hour at 30° C. *(1)*. More recently another routine autolytic procedure, which is based on the liquefying action of alpha-amylase on starch paste, has been made possible through the development of the Brabender Amylograph, a recording torsion viscometer which provides a continuous automatic record of the changes in viscosity of a flour-water suspension as the temperature is increased to 203° F. (95° C.) at a uniform rate *(6)*. The increase in viscosity due to gelatinization is opposed by the liquefying action of alpha-amylase, and the height of the curves at maximum viscosity is an index of the liquefying activity *(7)*. The inherent capacity of a flour to support gas production, that is the "gassing power," may be determined by measuring the gas production of doughs made under standard conditions without added sugar *(1)*.

In addition to these autolytic procedures, methods have been developed which permit the estimation of alpha- and beta-amylase activity in extracts of wheat and barley malts containing both enzymes. The estimation of alpha-amylase involves determining the dextrinogenic activity of the extract in the presence of an excess of beta-amylase by a modification of the Wohlgemuth procedure. This procedure, developed by Sand-

stedt, Kneen and Blish *(34)*, is based on their finding that increases in the ratio of beta- to alpha-amylase increased the rate of dextrinization up to a point beyond which further increments of beta-amylase were without any appreciable effect. By adding an excess of beta-amylase the method was thus rendered specific for alpha-amylase. It is important to note that this method was developed for determining the alpha-dextrinogenic activity of malts and its applicability to the measurement of alpha-amylase activity of fungal and bacterial preparations has not been established. Redfern and Landis *(32)* have shown that the three types of alpha-amylase differ quantitatively in their action upon starch; thus, liquefaction rate curves for equivalent alpha-dextrinizing amounts of amylase from these sources were not superimposable.

The determination of beta-amylase in wheat and barley malts (that is, in the presence of alpha-amylase) which was developed by Kneen and Sandstedt *(22)*, is based on their finding that the saccharogenic activities of the two enzymes were additive over a wide range in relative concentrations. The total saccharogenic activity of the extract is determined on soluble starch under standard conditions. The beta-saccharogenic activity is obtained by subtracting the saccharifying activity due to the alpha-amylase which is present. This is accomplished from the known relations between alpha-dextrinogenic and alpha-saccharogenic activity which have been determined with an alpha-amylase preparation.

Factors Which Influence Various Measures of Amylase Activity in Wheat Flours

Several studies have established that the quantity of available or susceptible starch, rather than the concentration of beta-amylase, is the limiting factor governing the results of autolytic tests on sound wheat flours *(14)*. Thus, the maltose value of a flour may be increased by overgrinding in a ball and pebble mill. In the flours released at various stages in the roller milling process there is a high correlation between maltose value and the percentage of starch granules over 20 μ in diameter which are stainable with congo red. The extent of starch damage has been found to depend upon such factors as the hardness of the wheat, the moisture content of the wheat mix going to the first break rolls, and the extent of mechanical action (which varies with the number of passages through the rolls; roll pressure, speed differentials, and fineness of grinding).

The maltose value determination was extensively used for many years in production control as an index of the ability of a flour to support gas production. However, in 1937 and 1938 several workers noted that the correlation between these two variables was not sufficiently high to justify the use of the maltose value determination as a substitute for the more tedious and cumbersome gassing power test *(5, 12, 13)*. Sandstedt et al. *(33)* found that if the time of autolysis is extended, the rates of maltose production decrease and that the extent of the decreases differed widely for different flours. This suggests that the decrease in rate is a function of variations in the quantities of susceptible starch which are present and that a better differentiation between flours and a maltose value more closely associated with gassing power might be obtained if the time of autolysis was extended. That this is the case has been shown by recent studies conducted by Chiang and Geddes *(9)* of the relations between maltose production in various time intervals and gassing power, as well as other variables. The results summarized in Table 1 show that the correlations improve when the autolysis time is increased. Such a modification of the maltose value test would eliminate the advantage of rapidity. As the gassing power test is a more direct measure of the ability of a flour to support yeast fermentation, it has largely replaced the maltose value determination. Numerous devices, some of which are automatic, have been developed in recent years to simplify the gassing-power test.

TABLE 1

Correlations Between Maltose Production and Other Variables for Data Obtained With 33 Untreated Mill Stream Flours From a Hard Red Spring Wheat Mill

Digestion Time	Correlation Coefficients Involving Maltose Production [a]				
	Gassing Power	Beta-amylase	Alpha-amylase	Starch Resistance [b]	
				Physical	Chemical
hrs.					
1	+0.61	N. S.	N. S.	+0.36	+0.66
2	.92	N. S.	+0.45	.55	.82
4	.93	+0.58	.67	.51	.71
6	.89	.66	.78	.49	.62

[a] "N.S." designates that the correlation was not statistically significant.

[b] The determination of starch resistance by the "physical method" was based on a count of the percentage of granules 20 μ in diameter or larger which stain with Congo red. In the chemical method a definite amount of an alpha-amylase preparation was added to each sample and the maltose production measured. The relative increases in maltose value due to this addition served as a measure of the starch resistance.

Mill Control of Amylase Activity of Wheat Flours

An adequate level of alpha-amylase is essential to ensure sufficient gas production and to produce the desired modification in starch properties during baking. As flours milled from sound wheat contain only very small amounts of this enzyme, it has been standard practice of the U. S. millers of bread flours for the past twenty years to maintain the maltose value or gassing power of the flours they produce at a level which will prevent yeast starvation under the usual systems of baking. As intimated earlier, the trend during the past few years has been to maintain higher levels than were previously common. The definitions and standards of identity for flour, effective January 1, 1942, under the Federal Food, Drug, and Cosmetic Act of 1938, permit the miller to use malted wheat, malted wheat flour (not exceeding 0.5 percent) and malted barley flour (not exceeding 0.25 percent) singly or in combination, to compensate for any natural deficiency in amylase activity.

Since both the desirable and undesirable effects of amylase supplements in breadmaking depend primarily on their alpha-amylase activity, the Lintner value of a malt, which is based on its ability to convert gelatinized starch to maltose and is largely a measure of its beta-amylase activity, is of no utility in evaluating malts for breadmaking. Moreover, since the response obtained

upon adding a constant percentage of a malt supplement of a given alpha-amylase activity to different flours will vary depending primarily upon the susceptibility of the starch, the dosage of supplement which is required to secure a desired level of activity must be obtained by adding various increments of the amylase supplement to the flour under study.

By plotting the measure of amylase activity employed against the malt dosage, the amount of malt required to give an arbitrarily selected level of activity may be estimated. Hildebrand and Geddes *(17)* found that the relationship between malt flour dosage and maltose value of the diastated flour took the form of a quadratic curve whereas the gas production of such blends varied directly as the logarithm of the dosage of malt flour. The latter relation therefore provides a convenient means of estimating the malt dosage required to obtain a given level of amylase activity. It must be emphasized that the response per unit dosage of malt decreases as the level of supplementation is increased. Accordingly, the accuracy of the estimation of the required dosage from maltose value or gassing power determinations is not as great for the higher as for the lower levels, since the response is limited by the quantities of susceptible starch which are present.

The liquefying action of alpha-amylase may also be employed for production control purposes *(8, 35)*. In view of the recent trend towards higher levels of supplementation, it is not surprising that increasing use is being made of the amylograph in controlling the dosage of malt flour. Selman and Sumner *(35)* have pointed out that the peak viscosity of a flour suspension upon gelatinization is more sensitive to changes in malt activity and malt dosage, and less sensitive to milling damage, than either maltose value or gassing power. Accordingly, the amylograph is a more appropriate means of measuring the primary effects of malt during the baking process. These workers give the following optimum ranges for the amylolytic activity of bread flours: amylograph units, 400 to 600; gassing power (manometric method), 540 to 575 mm.; maltose value, 370 to 400 mg.

Utility of Cereal, Fungal and Bacterial Amylases in Breadmaking

Although the malts of wheat and barley are the only supplements which are permitted in the current definitions and standards of identity for flour, there has been considerable interest in amylase preparations from certain molds. Molds, such as certain strains of *Aspergillus oryzae*, usually grown on cooked wheat bran *(42)*, produce an amylase of the alpha-type but which is more thermolabile than the alpha-amylase of wheat or barley malt; in contrast bacterial alpha-amylases, produced by selected strains of *Bacillus subtitlis* or *B. mesentericus*, have higher thermostability than malt alpha-amylase *(3)*.

Researches at Kansas State College have recently been reported on the effects in breadmaking of alpha-amylase preparations obtained from cereal, fungal and bacterial sources *(11, 19, 20, 24, 25)*. In these studies, extracts corresponding to dosages up to 24 times the normal supplementation with malted wheat or barley flour were employed. Even at the highest concentrations, positive responses in the quality of the bread were obtained by a straight dough baking procedure; in sponge dough baking procedures, however, high levels of an extract of fungal bran preparation caused soft sticky doughs, which produced bread of low loaf volume, and of inferior grain and texture. These detrimental effects were attributed to the high protease activity of the fungal extracts since inhibition of the protease activity by the addition of sodium chloride to the sponge or adsorption of the proteases on kaolin permitted the use of high levels of these extracts without harmful effects. Fungal alpha-amylase was less effective than equivalent concentrations [c] of alpha-amylase from malted wheat or barley in decreasing the maximum viscosity of gelatinized starch; this is associated with the lower thermostability of the fungal amylase. By employing appropriate conditions for the differential inactivation of alpha-amylase and the proteases, it was found that while alpha-amylase is largely responsible for the decrease in dough consistency at normal concentrations of a supplement, increasing concentrations had little further effect whereas proteinase progressively decreased the dough consistency as the levels were increased. Previous workers have ascribed the decrease in dough consistency upon the addition of amylase supplements to the liquefying effect of alpha-amylase but Miller and Johnson have pointed out that the mellowing action of proteinase is an important contributing factor, particularly when an enzyme preparation with a high ratio of proteinase to amylase is employed *(25)*.

Conn et al. *(11)* employed commercial bacterial and fungal enzyme concentrates as amylase supplements in breadmaking in comparison with malted wheat flour. The fungal preparations gave satisfactory results when the ratio of proteinase to alpha-amylase was not excessive but the bacterial preparations yielded unsatisfactory bread of a sticky and gummy character. These results support the view of many workers that bacterial amylase preparations would be unsuitable for use in flour supplementation since they would likely cause excessive liquefaction and dextrinization of starch during baking because of their high thermostability. The sticky and gummy character of the bread crumb when the bacterial preparations were used was associated with their amylase activity and may perhaps be associated with the relatively low affinity of these bacterial alpha-amylases for dextrins of low molecular weight *(11)*.

Differences in the thermostability of malt and fungal alpha-amylases imply that equivalent concentrations of alpha-amylase when measured by their effects on flour maltose value will show widely different liquefying activities as measured in the amylograph. This is clearly illustrated by the data of Harrel *(16)* in Table 2. These results indicate that given gassing power can be obtained with widely varying baking effects by use of either malt or fungal supplements or combinations of them.

[c] The alpha-amylase activity of the various sources of alpha-amylase was determined by the dextrinogenic procedure designed by Sandstedt et al. *(34)* for malts.

Lipases

Little attention has been paid to the lipases of cereal grains although they are presumed to be of great importance in the deterioration of cereals and cereal products. It is well known that a fat-splitting enzyme which acts on the glycerides of the fatty acids to a greater extent than on simple esters of these acids occurs in wheat. Glycerides of the lower fatty acids, particularly triacetin, were found by Sullivan and Howe *(40)* to be the most readily hydrolyzed. These investigators found that the lipase activity of clear and low-grade flours was higher than that of patent flours, germ or bran, which indicates that the lipase is largely concentrated in the scutellum and the aleurone layer.

TABLE 2

Effects on Gassing Power and Liquefaction of Supplementation to Similar Maltose Levels With Malt and Fungal Alpha-Amylase [1, 2]

Supplement	Maltose Value	Peak viscosity	Gassing power
	mg.	*B. U.*	*mm. Hg. pressure*
None	280	565	387
Malt, 0.1 percent	326	260	470
Fungal, 0.015 percent	342	545	540
Malt, 0.5 percent	425	65	.....
Fungal, 0.08 percent	425	500	.....

[1] A southwestern patent flour 0.40 percent ash was employed. The malt supplement comprised a mixture of equal parts of a malted wheat and malted barley flour. The fungal source of amylase was an enzyme concentrate from *Aspergillus oryzae*.

[2] Table by courtesy of C. G. Harrel, Pillsbury Flour Mills, Inc., Minneapolis, Minnesota.

Recently Singer and Hofstee *(36, 37)* obtained a lipase from wheat germ in soluble and partly purified form and found that it acted on a large series of water-soluble simple esters, mono- and tri-glycerides and on the laurate and palmitate esters of sorbitan (Tween 20 and 40). The optimum pH under the experimental conditions employed was 7.4.

Miller and Kummerow *(26)* determined the lipase activity of a number of bread constituents using mono-N-butyrin as substrate, and found that bread wheat flours were of low activity in comparison with other baking materials. Thus, compressed yeast had approximately 500 times the activity of patent flour (uncorrected moisture basis). Fungal amylase concentrate had a higher activity than malted barley. Bread which was baked with the inclusion of 10 percent defatted wheat germ in the formula, to increase the lipase activity of the dough, was completely devoid of fat-splitting activity.

When cereals and cereal products are stored, there is an increase in fat acidity, the rate of increase being greater at higher storage moistures, particularly at moisture levels which permit mold growth *(10, 27, 28, 39, 43)*. However, at high moisture levels there is relatively little increase in fat acidity when the mold growth is inhibited by storing the grain under nitrogen. While the fat acidity of grain is commonly regarded as a good measure of its commercial condition *(43)*, there is no specific knowledge concerning its origin or nature. It is a reasonable inference that the increase in fat acidity is a result of the action of the lipases of the seeds and of the molds (where the moisture level is sufficiently high to permit their growth). That molds may produce lipase in quantity has been shown by several workers *(10)*; Nagel and Semenuik *(31)* for example, grew cultures of nine fungi (obtained from naturally molded corn) on steam-sterilized corn containing about 32 percent moisture, and found that all fungi increased the fat acidity of the corn.

The hydrolysis of the lipids of flour and other stored cereal products is accelerated by increasing the moisture content and the storage temperature and it has been assumed by many investigators that the increase in fat acidity is an accurate measure of lipase activity. Small amounts of unsaturated acids such as oleic, linoleic and linolenic acids result in short brittle glutens yet these acids only have a pronounced deleterious effect in bread-making when they become oxidized either by the air or by the lipoxidase in the flour *(39)*. Both hydrolytic and oxidative rancidity may occur in uncooked cereals and cereal products; the former being favored by a high moisture content and the latter by low moisture levels *(2)*. In many types of cake premixes, the development of hydrolytic rancidity results in cakes which are excessively crumbly and have poor eating quality. Therefore an effort is made to pack and maintain these preparations at a moisture content which will limit the development of fat acidity but which will not result in a marked increase in oxidative rancidity. The stability of the shortenings used in these mixes is considered to be an important factor.

The role of lipases on the storage behavior of cereal grains and their milled products cannot be adequately evaluated until more information is available on the properties of these enzymes. Further researches are needed to establish definitely whether the increase in fat acidity is due to lipase activity, and to determine the origin of the fatty acids; that is, whether they arise entirely from the hydrolytic cleavage of the glycerides of the grain or are also produced in part at the higher moisture levels by the synthesis of fatty acids from carbohydrates through the metabolic activity of molds.

Lipoxidase Activity

The existence of an enzyme, lipoxidase, in soybeans which oxidizes carotenoid pigments during the peroxidation of the naturally occurring, higher unsaturated fatty acid residues (linoleic, linolenic and arachidonic acids) has been established *(4)*.

The relatively high concentration of lipoxidase in unheated soybean meal has led to a patent covering the use of such a soybean product for the bleaching of the flour pigments during dough fermentation *(15)*. Recently, it has been shown by Irvine and Winkler *(18)* that lipoxidase is responsible for the marked destruction of the xanthophyll pigments which occurs in macaroni doughs during the mixing stage of the macaroni-making process. The percentage of the pigments present in the semolina which is destroyed during processing varies from about 20 percent for the best durum wheat varieties to about 60 percent for the poorest ones. The rate of destruction during the mixing stage increases upon increasing the absorption to about 33 percent and upon increasing the dough temperature or the oxygen tension of the atmosphere.

The presence of lipoxidase in wheat germ has been demonstrated by Sumner *(41)*. More recently, Miller and Kummerow *(26)*, employing carotene as a substrate, have found that patent flour contains much smaller quantities of lipoxidase than clear flour, bran, shorts and germ fractions.

Lipoxidase activity may be responsible, in some measure, for the bleaching of flour which occurs upon natural aging and for the development of oxidative rancidity in cereals and cereal products. Further investigations of the role of this enzyme in cereal technology are warranted.

Summary

Wheat flours milled from sound wheat contain only traces of alpha-amylase but have ample quantities of beta-amylase. An adequate level of alpha-amylase is essential in yeast-leavened products to insure a sufficiently high rate of gas production to leaven the dough, to provide residual sugar to give appetizing bread with desirable crust color and to yield bread of desirable softness and eating qualities. Amylase activity during dough fermentation depends largely upon the extent to which the starch has been mechanically injured during milling. Autolytic methods of controlling the malt dosage, such as determining the amount of maltose produced by a flour suspension or the gas production of doughs made without added sugar, fail to give satisfactory differentiation of high alpha-amylase levels, and there is an increasing tendency to employ the extent of liquefaction during gelatinization in the amylograph for control purposes.

Upon the storage of wheat and flour, the fat acidity increases, the rate of increase being more rapid as the moisture content and temperature of storage are increased. Unsaturated fatty acids produce short brittle glutens and, when oxidized, flour containing them yields doughs of inferior handling properties and bread of poor volume, flavor and taste. Hydrolytic rancidity of flour and of premixes is presumably due to lipase activity.

Lipoxidase oxidizes carotenoid pigments during the peroxidation of certain of the naturally occurring unsaturated fatty acid residues in fats. It brings about the partial destruction of carotenoid pigments in bread and macaroni doughs and may be responsible, in some measure, for the bleaching of flour which occurs upon natural aging as well as for the development of oxidative rancidity in cereals and cereal products. This type of rancidity is favored by storage of these products at low moisture contents.

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Quality of Fresh and Frozen Fish and Facilities for Freezing, Storing and Transporting Fishery Products[a,b]

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The relation between quality and length of storage period is shown graphically for unfrozen and frozen fish having relatively good keeping characteristics. Various methods for the commercial preservation of fish by freezing are briefly discussed.

Much has been written on the freezing method of preserving fishery products. The subject has been covered from substantially every aspect of interest to the technologist, so that if knowledge in itself were the key to high quality, one would expect that nothing but excellent frozen fish would be marketed in America today. Since that is far from the actual condition, there must be some explanation for the lag between knowledge and its application. The present paper will present views that might throw some light on the present situation in the frozen fish industry, and raise points for consideration and discussion not only in technological groups but, it is hoped, within the membership of the fishing industry too. Along the way, principles will be outlined, but no claim will be made for their economic feasibility if applied with the present handling techniques. Some further experimentation will be required to test consumer reaction and retail facilities before sound procedures can be formulated.

Throughout the entire food industry quality and standardization are key words today, and the frozen fish industry is no exception. But although quality of the unprocessed and processed products is looked upon as a must, and the factors affecting quality are well understood by the technologists at least, the trade itself is doing surprisingly little to raise the standards. Perhaps this is partly due to the lack of completely satisfactory measurements of quality, particularly in the unfrozen products. Nevertheless what measurements we do have indicate that the present techniques of handling fish destined to be frozen are seriously faulty.

Support for this statement can be obtained through consideration of the post-mortem history of fresh fish in general. At the moment a captured fish dies, changes are initiated that eventually will render the fish unfit for human consumption. These changes, due to bacterial, enzymic, oxidative and hydrolytic activity, are greatly affected by temperature; therefore the good fisherman uses ice to preserve his catch. At the temperature of melting ice, each species of fish will have a shelf life which will depend somewhat upon sanitation and good housekeeping practices of the fishermen. That is to say, all other things being equal, each species will keep just so long on ice before it is rendered useless or its quality, as far as freezing is concerned, will be nil.

This concept can be shown graphically by plotting a quality curve as illustrated in Figure 1. The quality of a fish will be a maximum (100 percent) when the fish dies, and it will be zero at the end of a definite period on ice. For discussion purposes the shelf life in Figure 1 for fresh fish has been arbitrarily taken as three weeks.

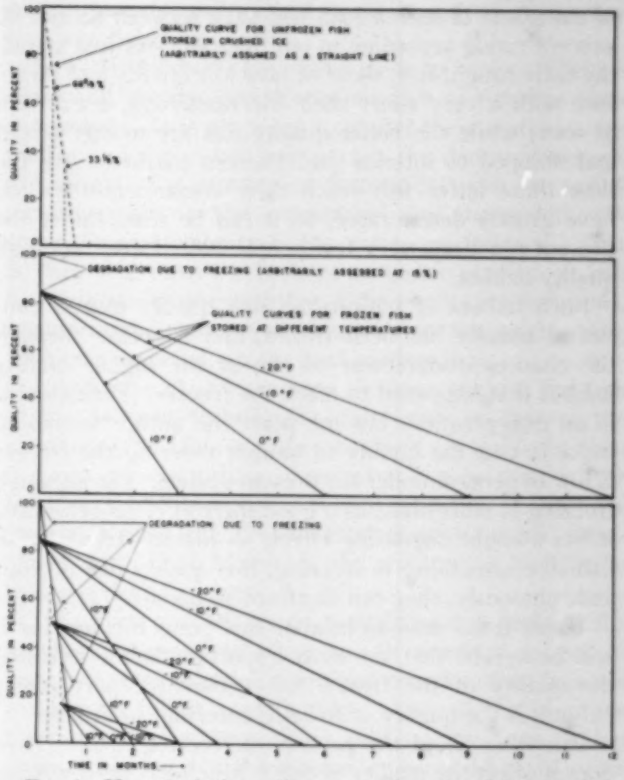

FIG. 1. Hypothetical quality curve for the fish stored in crushed ice.

FIG. 2. Quality curves for frozen fish stored at different temperatures.

FIG. 3. Graphs showing the effects of combining Figures 1 and 2.

It must not be overlooked that the factors governing the shelf life of fish in ice do not necessarily act at a constant rate throughout the storage period. That is, there are lag periods or induction periods. Therefore the quality curve joining the point 100 percent quality and time zero with zero quality and time 3 weeks will not necessarily be a straight line as shown. Since the true curve is not known, for discussion purposes a straight line relationship has been assumed.

On this assumption, then, the quality of this particular species of fish will be 66⅔ percent at the end of one week and will be 33⅓ percent at the end of two weeks storage in ice. There are not many species of fish with a shelf life beyond three weeks; indeed most fish have a much shorter shelf life. Relate this observation

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[b] Issued as paper No. 249 of the Canadian Committee on Food Preservation.

with the size of America and distribution of the markets and it readily will be realized that in Canada and the United States, in general the quality of unfrozen fish consumed is indeed very low.

Just to confirm this observation it might be convincing to have a specific example, and for that example the Pacific halibut fishery will be taken. Because of the remoteness of the more productive halibut banks on the Pacific coast, halibut schooners often take as long as three weeks for a single trip, and the first-caught fish may be as old as 15 to 18 days when landed at the dock or cold storage plant. According to our quality curve this fish is below the 33⅓ percent of quality level, and it has a very short shelf life remaining; therefore it of necessity goes into the freezer immediately. The quality of the whole of such a load will vary between 85 and 20 percent rating according to our diagram. As just stated, the early caught fish, those of now low quality and therefore with a very short shelf life remaining, are frozen at once, while the better quality fish are mostly boxed and shipped to interior and Eastern markets. By the time these latter fish reach their consumers they too have greatly deteriorated, so it can be seen, under the present practices, very few people indeed ever get high quality halibut.

Such halibut of reasonably high quality that is consumed usually has been frozen, and it occurs through the chance procurement of one of the higher quality halibut that happened to reach the freezer. Perhaps this is an exaggeration, but the point the author wishes to make is that the quality of halibut entering the freezer is low in general under the present system. For although freezing is recognized as a good method of preservation, it has a slight degrading effect, so just as strictly fresh fish lose something in freezing, low quality fish do too; and, obviously, they can ill afford to do so.

There is no need to belabor this point further, for it will be agreed that the most important factor affecting the quality of the frozen fish consumed, particularly halibut, is the quality of the fish entering the freezer.

But what about the process of freezing itself? How does it affect the quality of fish? Much has been written on the physical and biochemical effects of freezing with various theories advanced. What the fishing industry is mainly concerned with, however, is the effect of freezing on consumer reactions and on nutrition. There is much evidence to show that freezing fish has negligible effect on its nutritive value, but the effect on consumer reaction is not fully explored. For purposes of discussion results obtained in some of the investigations by the Fisheries Research Board of Canada will be cited *(5, 6)*.

The investigations referred to were of a subjective nature, and subjective tests never give precise results. In these experiments about thirty families were used in addition to a selected tasting panel. Some of the factors investigated were: (1) Rapid freezing; (2) Slow freezing; (3) Rapid vs. slow freezing; (4) Storage temperature level vs. rapid and slow freezing; (5) Aging of unfrozen fish; (6) Aging vs. slow freezing.

The most extensive experiments were conducted with halibut and salmon at the West Coast Technological Station at Vancouver and with cod and haddock at the East Coast Station at Halifax.

It might be observed that wherever possible, absolute controls were used. That is, in the assessment of the effect of rapid and slow freezing for example, parts of the same fish were used. Only in those experiments involving prolonged storage were controls not used. In these latter experiments, obviously the studies entailed mere comparisons between samples variously treated. The samples compared, however, were always from the same fish.

Although the results from these experiments were not clear cut and did not give precise figures, they did permit the drawing of some interesting deductions. On the basis of those deductions and the deductions of workers in Great Britain *(1, 2, 3, 4)* where similar investigations were carried on, Figure 2 has been prepared.

Here the degradation due to freezing has been arbitrarily assumed to be equal to about 3½ days storage in ice or 15 percent reduction in quality. This is approximately what was deduced from the studies with slow frozen vs. unfrozen aged fish.

The straight lines showing the decline in quality with time at the various cold storage temperatures are again arbitrary, and stem from our own studies and those in Great Britain; but since it is not safe to generalize too freely, separate curves would have to be worked out for each species of fish. Figure 2 is meant to be for illustrative purposes only, and would apply to fish with relatively good storage characteristics such as halibut. It is believed that when frozen strictly fresh, halibut can be kept for 12 months at —20° F. (—28.9° C.); 9 months at —10° F. (—23.3° C.); 6 months at 0° F. (—17.8° C.), or about 3 months at +10° F. (—12.2° C.) and still be edible though its quality will be low. For discussion purposes quality has been set at zero percent at the end of these respective periods as shown.

Now if Figure 1 is a reasonable representation of quality against time for a species of fish in the unfrozen state, and if Figure 2 is a fair representation of quality in the frozen state for that same species, then some very interesting and illuminating speculations can be made by combining the two figures. Figure 3 illustrates what might be the result if the above hypotheses are valid.

For the purposes of illustration three grades of fish, frozen and stored at four different temperatures, are shown; requiring 12 curves to show the relation between quality and time for all the samples.

The upper four graphs give the quality relations for fish of 100 percent quality going into the freezer. These fish, according to the hypothesis already given, will lose 15 percent in quality during the few hours required for freezing; after that their quality will follow the slope for the respective storage temperatures.

The middle four graphs give the quality relations for fish held on ice for one week before being frozen. These will have a quality rating of 66⅔ percent on entering the freezer and a rating of 51⅔ percent after being frozen. It will be noticed that their respective shelf or

storage lives have been reduced to something like $\frac{2}{3}$ of that in the upper graphs.

The bottom four graphs show what might happen with fish stored for two weeks on ice before being frozen and stored. Under these conditions the shelf lives have been so greatly reduced that one wonders whether freezing is worthwhile at all, in view of the low quality of the product being handled.

If we were to continue these speculations and freeze fish stored for three weeks on ice, theoretically we would get frozen fish with a negative quality rating. Since all the graphs represented can be expressed in simple algebraic terms, by supplying the proper values for the constants or by extending the storage period beyond that given by the intercept of the curve with the time axis, then mathematically also a negative quality results.

In the practical sense this would appear to be impossible. But from the standpoint of the technologist and based on the foregoing analysis, much of the frozen fish now in cold storage has negative quality, yet all will go on the market and will eventually be consumed. This fish with negative quality, therefore, appears to have commercial value equal to that with a positive quality rating, but it is not unreasonable to suppose that the fish with negative or low quality ratings will have some unfavorable effects on the future sales of frozen fish. For that reason perhaps a negative rating is not impractical and uneconomic. At any rate, there is food for thought here if not for the digestive system. Perhaps all of you, at some time or other, have had placed before you fish of very doubtful quality, and the results have been that your appetite for fish was lowered seriously. Such fish can be classified as having negative quality, for its effect has been not to raise, but rather to lower the potential consumption of fish, which is a decidedly detrimental effect.

Just how much of the frozen fish being consumed has what we might term negative quality, is difficult to estimate for the very good reason that there is no reliable means of determining quality in frozen fish. But from what is known of the postmortem history of frozen fish in general, it is evident that the present techniques of catching and handling preclude the marketing of fish that has a uniformly high quality rating.

A thoroughly reliable and quick means of determining quality in all species of fish has not been evolved yet. But even if satisfactory tests were available, the best it would do is tell us just what we are handling. It would still be up to the fishermen, processors and handlers of fish to do something about raising the standards. It would seem we already know enough about the fishery products sold to do something about quality. If the consumption of fish is to be raised in America, the means of doing this lies in changes in techniques of handling. It is extremely important that the consumer be given fish that will induce repeat orders rather than fish that lowers the appeal, as now seems to be the case with many species.

One change in practice that could obviously raise the quality of frozen fish in general, is to freeze the fish within a very short time after they are caught. With fish such as halibut and tuna, that necessitates freezing the fish on the fishing vessels. It is common practice to freeze tuna right on board the tuna clippers, but so far, halibut are not being frozen aboard commercial halibut schooners on our Pacific coast. It is claimed to be impractical and uneconomic.

As stated earlier, the feasibility of commercially applying the principles outlined in this paper is outside the scope of this discussion. But it might be observed that a project is now planned by the Fisheries Research Board through its Vancouver Station whereby a 57-foot fishing vessel with a metal hull will be equipped with facilities for freezing fish aboard, so that halibut and other fish that are captured long distances from ports can be frozen soon after their capture. By means of controls stored in ice at the same time, with the aid of tasting panels and other measurements comparative tests can be made.

In Canada surveys have been made in various Eastern cities and the per capita consumption of fish has been determined. It is proposed to gather these statistics annually, and these data will permit the determination of the effects of a number of factors that can be varied experimentally in the expectation that the results will show the practicability of the variations induced. That is, they will form the basis of economic studies. It can be fairly safely assumed that if the results are favorable, engineers will soon find solutions to the engineering problems involved, on the boat as elsewhere.

Regardless of the outcome of these studies, the role of the fisheries technologist must ever be that of the missionary or pioneer. He must first get the facts, then through demonstration, show what can be done in the light of this knowledge. When once the objects are clearly defined the details soon seem to work themselves out. That is true in the sciences as well as in their application.

Defeatism and laissez-faire attitudes are perhaps the greatest deterents to progress. If research is not at least five years ahead of industrial practice, then it is not making its fullest contribution. Some of the ideas we have seen applied recently in cold storage construction were worked out in the laboratory some 15 to 17 years previously, so the investigator should not be easily discouraged. If industry has the characteristics of the proverbial mule, then the technologist must assume the character of the mule team driver. That is, he must be just a little more persistent or stubborn, if you like, than the mule, in order to get ahead with his load.

Before concluding I would just like to review in a few words the status of the facilities presently available for the freezing, holding, transporting and retail distributing of frozen fishery products.

Given the raw product of the desired high quality, facilities are available for its rapid freezing if its dimensions are sufficiently restricted. There are available plate-type freezers for packaged commodities and air- and immersion-type freezers which are designed for products of irregular shapes and various sizes. These seem to fill the requirements for the numerous fishery products now being handled. There seem to be no insurmountable obstacles to the application of these systems on boats.

Now that the need for lower storage temperatures is recognized, practically all fish cold storage plants maintain sub-zero temperatures in their holding rooms. The newer plants are holding temperatures of —10° F. (—23.3° C.) and lower in Canada. Desiccation of the fish is prevented by the use of improved glazes and improved designs of the storage rooms employing the use of jackets or modified forms of jackets.

Rail transport facilities capable of holding sub-zero temperatures are not in commercial use yet, but investigations into the various means of refrigerating railway cars will likely result in a satisfactory system that will fulfill the needs for all perishable fishery commodities within the next few years.

Trucks and trailers capable of holding sub-zero temperatures are already available, so that communities accessible by paved highways are now potentially expandable markets for improved fishery products.

Retail dispensing equipment suitable for frozen fish is also available. It is not being used as extensively as might be, but perhaps fuller use will come with a greater dissemination of knowledge.

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A New Principle for Agitating in Processing of Canned Foods[a]

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A new principle for agitating in processing of canned foods, which enables the use of higher temperatures with a resultant decrease in the time needed to sterilize foods in sealed cans, has been developed.

The technique involves end-over-end rotation of the sealed can during processing at a speed such that the centrifugal force acting upon the can approximates the force of gravity. This permits heat penetration of the most rapid rate in products having one liquid, or semi-liquid component, and normal headspace.

Considerable improvement in the texture, flavor, color, and thiamine retention of many "heat sensitive" products has been achieved with no overcooking or scorching taking place. The principle is particularly applicable to the large can sizes and now enables many products to be sterilized without danger of appreciable deterioration in quality.

Experience has shown that the factors of quality in canned foods such as color, flavor, texture, and vitamin content are most efficiently preserved by the higher temperature—shorter time processes *(1, 2)*. Appert's early attempts at canning involved heating glass bottles of foods in water for long periods of time. While low acid canned foods may be sterilized at relatively low temperatures, excessively long times are required with the result that the quality is usually materially affected. Following the early use of the "tin can" came higher temperature processes in salt solutions and later the introduction of the pressure retort. As more knowledge developed on the heat resistance of microorganisms in canned foods, it became more imperative to use the pressure retort and temperatures of approximately 240° F. and higher to insure safe and wholesome canned foods and to retain as much as possible the desirable quality characteristics of the products. In general it may be postulated that the destruction of bacteria increases tenfold for each 18° F. (10° C.) rise in processing temperature, while the chemical reactions responsible for product deterioration are only doubled. Bacteriologically equivalent processes for shorter times at higher temperatures effect a greater preservation of the natural characteristics of the products being canned. Commercially such processes may be accomplished through tubular "flash" sterilization of liquid and semi-liquid products and aseptic filling and closing *(3)* or agitating processes of liquid and semi-liquid products within the can *(4)*.

The scientific determination of processes for canned foods involves the correlation of the thermal death times of the most resistant bacteria which may cause spoilage of the food with the rate of heat penetration in the canned food when heated at some specific temperature. In still processes, liquid and semi-liquid products are heated mainly by convection. Increase in viscosity and the presence of discrete particles retard the rate of heating by convection. Many semi-liquid products are heated by both convection and conduction and processes are necessarily long due to the slow rate of transfer of heat to the "cold-spot" of the can contents. Movement of the contents along the walls of the cans in such instances is slow and overcooking or scorching of the product often takes place. In the larger can sizes this problem increases to the extent that many somewhat viscous semi-liquid products and some of the more heat sensitive vegetable products cannot be satisfactorily sterilized due to serious overcooking and accompany-

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ing undesirable color and flavor changes. An efficient method for agitation of such products to produce the greatest mobility of the can's contents with the least product damage has been greatly needed by the industry.

In review of agitating processes at our laboratory a number of years ago, it was apparent that no basic study of the efficiency of the various methods of agitation of cans on the rate of heat penetration had ever been conducted or was available as common knowledge. It was obvious that a method of agitation of cans which would give a very rapid come-up of the can's contents to retort temperature would offer many advantages, for example:

1. Higher retort temperatures in the neighborhood of 260°, 270°, and 280° F. (126.7°, 132.2°, and 137.8° C.) could then be used with close control of process time and without scorching or overcooking the more viscous semi-liquid or heat sensitive natural products.
2. Many products with liquid as one component could be improved by a quicker come-up of the can's contents to presently used retort temperatures.
3. A rapid high temperature—short time method for sterilizing products in the can would improve color, flavor, and nutrititve value of many canned foods.
4. A wider range of processing time and temperatures would be available for various products in several can sizes thus allowing processes of the same F_o value to be selected on the basis of the degree of cooking desired for the individual products.
5. Many of the more viscous semi-liquid products and heat sensitive natural products could be sterilized in the larger can sizes without overcooking.
6. Heat resistant organisms could be destroyed in many products, especially in the larger can sizes, without heat injury to the product.

These were the objectives of the study, with the full appreciation that several types of agitating cookers were in successful commercial use. The question remained, however, as to what were the relative efficiencies of the different methods of agitating cans for the maximum rate of heat penetration.

An experimental agitating cooker was constructed (Figure 1) which was capable of agitating cans in numerous ways, principally those involving rotation or reciprocation. In this experimental retort rotational and reciprocational speeds of 0 to 360 r.p.m. and temperatures up to 300° F. (148.9° C.) could be attained. Air pressure was provided for pressure cooling and quick opening valves were used on the steam and water lines. The drive shaft was drilled for thermocouple leads and fitted with slip ring commutator connections to an automatic strip chart recording potentiometer. In the first basic studies 300 x 314 size cans filled with water to $\frac{5}{16}$" headspace were used, since this was a convenient size for laboratory work and it was felt that

FIG. 1. Experimental laboratory agitating retort.

the conditions would approximate those of the larger cans. It was established for the can under agitation that the "cold spot" was approximately at the center and therefore all thermocouple measurements were made at that point. In all of the tests the come-up time of the can's contents to within one degree F. of retort temperature was recorded on a strip chart recorder to accurately follow the temperature rise. The data presented herein represent large numbers of cans with the retort at a temperature of 260° F. (126.7° C.) and speeds from 0 to 200 rotations or reciprocations per minute.

Five different positions of the cans were tried with reciprocation with a one-inch stroke, three of which are shown in Figure 2. The two not shown are 90° rotations of S-2 and S-3. For position S-1, a two-inch stroke was also tried which showed a more efficient rate of heat penetration, but from a practical point of view seemed too vigorous for a commercial cooker. It will be observed that S-1 at 120 strokes per minute reduced the come-up time[b] from 60° to 259° F. (15.6° to 126.1° C.) from 4.3 to 1.4 minutes. The increased come-up time produced by low speed reciprocation with S-1 may be due to the conflict of natural convection currents with those induced by the shaking.

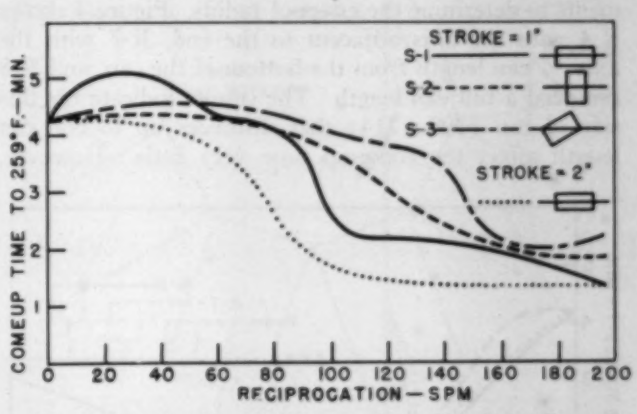

FIG. 2. A comparison of different means of reciprocating cans at varying speeds on the rate of heat penetration in 300 x 314 size cans of water.

[b] The term "come-up time" as used in this paper refers to the time in minutes required for the can's contents to reach a temperature 1° F. below retort temperature.

The effect of rotation with different axes and position of the cans is shown in Figure 3. It will be noted that the end-over-end types of agitation (R-2, R-3, and R-4) are superior at relatively low speeds with R-4 reducing the come-up time from 60° to 259° F. (15.6° to 126.1° C.) to 1.4 minutes. Rotational speeds are an important consideration since the type of agitation which results in a rapid rate of heat transfer with the least amount of mechanical work is to be preferred over other types of agitation with equal efficiency at higher rotational speeds. This is particularly true for the larger can sizes.

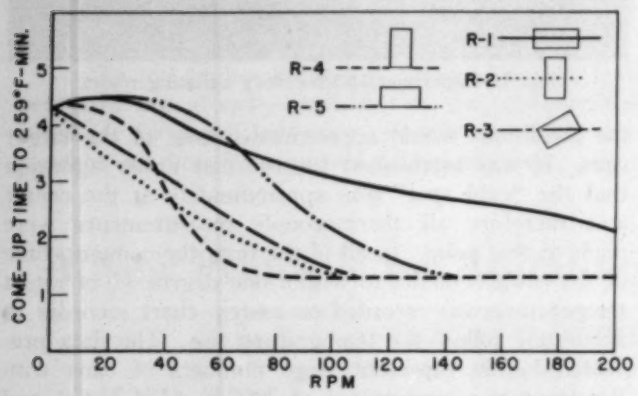

FIG. 3. A comparison of different means of rotating cans at varying speeds on the rate of heat penetration of 300 x 314 size cans of water.

End-over-end rotation of cans with the axes of rotation outside of the can were further studied by experiments to determine the effect of radius. Figure 4 shows R-4 with the axis adjacent to the end, R-7 with the axis ½ can length from the bottom of the can, and R-8 removed a full can length. The results indicate for this size of can (300 x 314) that distances up to one can length affect the come-up time very little. However,

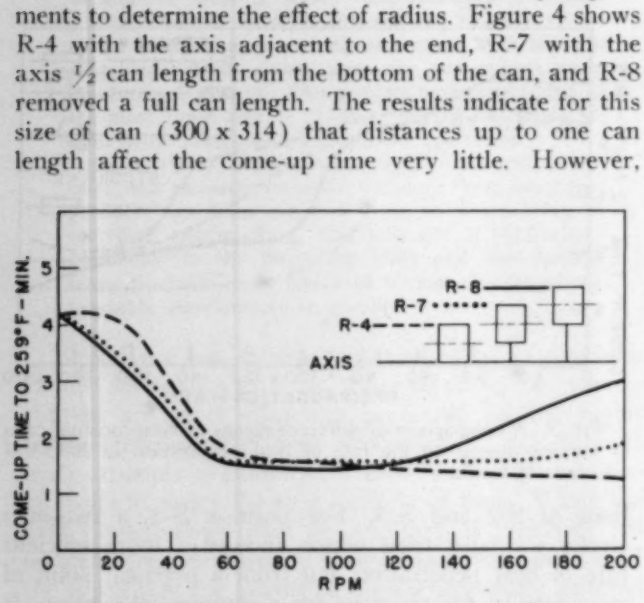

FIG. 4. Effect of radius on the heat penetration of 300 x 314 size cans of water rotated at varying speeds.

using other can sizes (No. 2) it has been found that when the radius from the center of rotation exceeded 6-8 inches, increases in come-up time were observed. The reasons for this will become apparent from the following discussion.

In Figure 5 comparisons are made of the best rotational agitation (R-4) with the best method of reciproca-

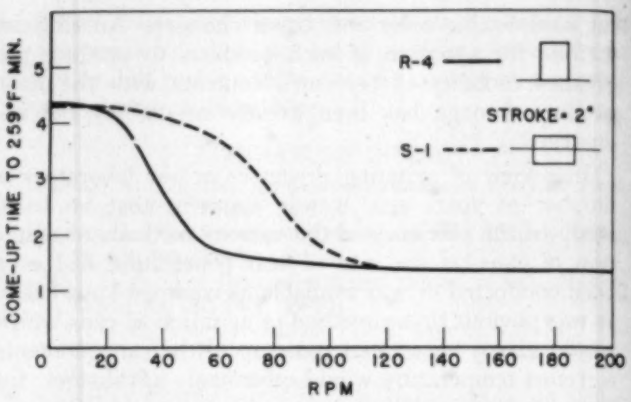

FIG. 5. A comparison of R-4 type of rotation with S-1 (two-inch stroke) type of reciprocation at varying speeds on the rate of heat penetration in 300 x 314 size cans of water.

tion (S-1 with a two-inch stroke) on the come-up time of 300 x 314 cans of water. These results indicate that end-over-end rotation at the proper speeds is superior, particularly in consideration of the amount of mechanical work involved.

In order to explain why end-over-end rotation is a superior means of agitating cans, a series of postulations were made, followed by attempts to prove them by actual demonstrations.

If a can containing a liquid and a headspace is turned slowly about an axis lying outside the can, the liquid level and headspace will assume the positions shown in Figure 6. Due to centrifugal force at a high speed the

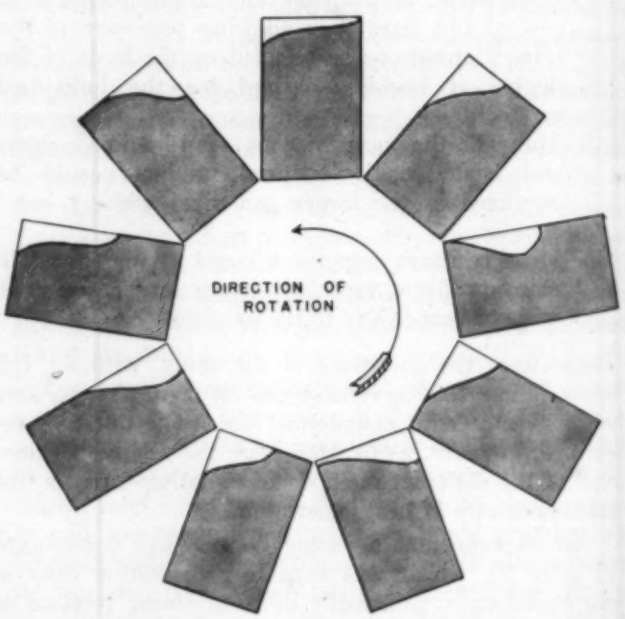

FIG. 6. Position of the headspace volume in a can containing a liquid when rotated end-over-end at slow speed.

liquid contents of the can will be forced out to the farthest end of the can and remain there during the complete cycle of rotation, the headspace under these conditions being at the end of the can nearest to the axis of rotation (Figure 7).

When a can containing a liquid such as water is rotated in a vertical plane with the axis of rotation outside the can, the weight of the liquid or the force of

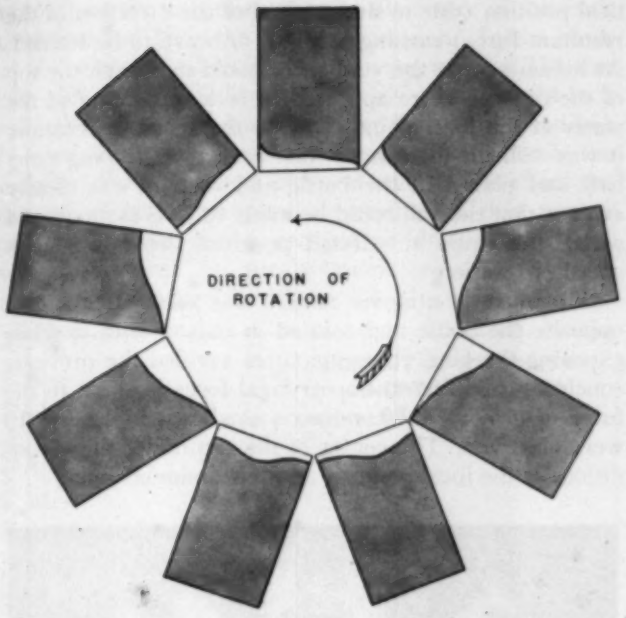

FIG. 7. Position of the headspace volume in a can containing a liquid when rotated end-over-end at high speed.

gravity is always vertically downward whereas the centrifugal force exerted on the contents is radially outward. Therefore, for each position of the can in a revolution, the centrifugal force (CF) is constantly changing with respect to the direction of the force of gravity (G).

When two or more forces act on a body, these forces can be resolved into a single resultant force. In Figures 8, 9, and 10 the resultant forces are shown with end-over-end rotation at speeds corresponding to CF<G, CF>G, and CF = G, respectively. As shown in Figure 10, the resultant forces intersect at a common focal point. The greater the centrifugal force, the closer

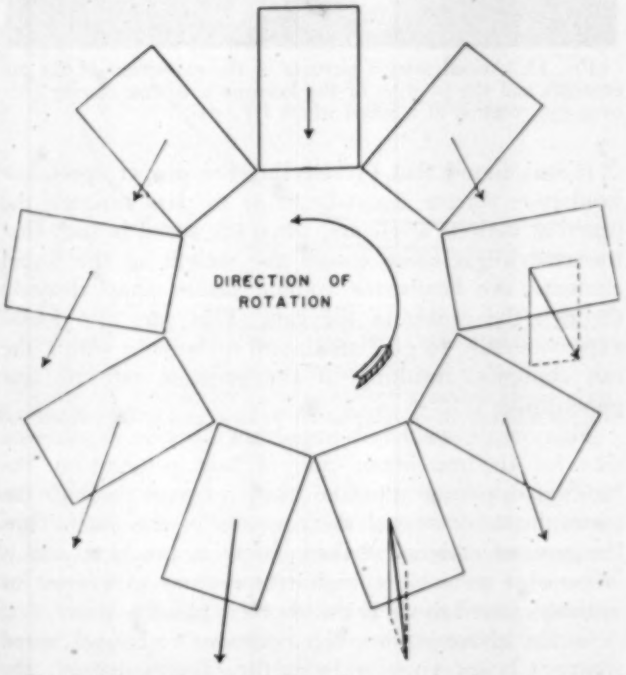

FIG. 8. Illustration of resultant forces acting in a can rotated end-over-end at a speed where CF = ½ G.

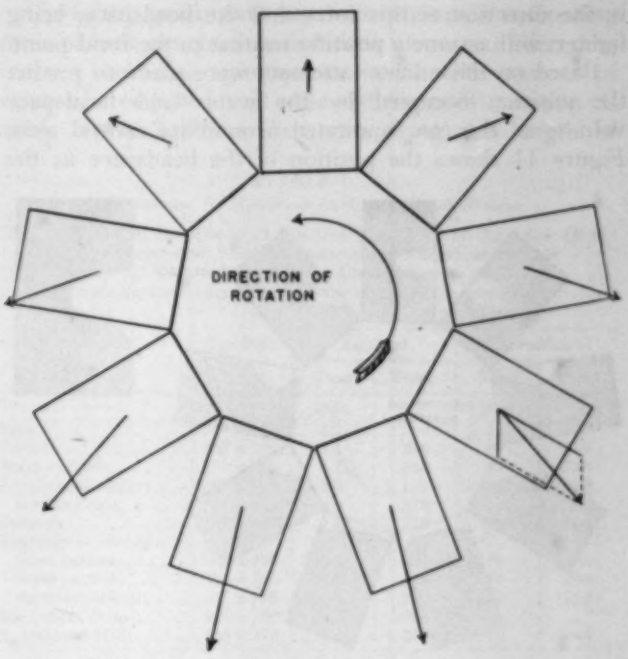

FIG. 9. Illustration of resultant forces acting in a can rotated end-over-end at a speed where CF = 1½ G.

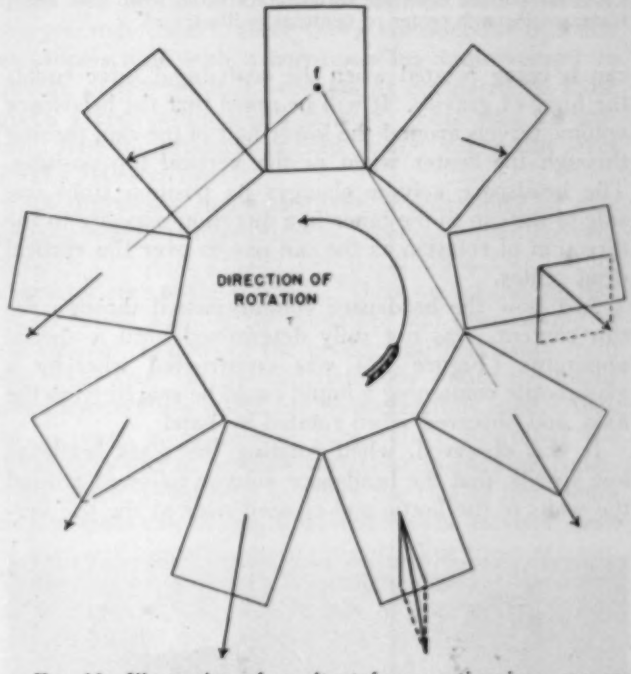

FIG. 10. Illustration of resultant forces acting in a can rotated end-over-end at a speed where CF = G.

this point approaches the axis of rotation. When centrifugal force is less than the force of gravity the focal point is above the middle or outside of the can, while with a centrifugal force greater than the force of gravity, the focal point is below the middle of the can and sometimes inside the path of the bottom of the can. When the centrifugal force is equal to the force of gravity, the focal point is in the center of the can as shown in Figure 10 by point f. For every value of centrifugal force, the location of the focal point will differ. As the resultant force always radiates from the focal point, this force will cause the liquid in the can to be driven

in the direction of this force and the headspace, being lighter, will assume a position nearest to the focal point.

Based on these facts, attempts were made to predict the position occupied by the water and headspace volume as the can is rotated around its central axis. Figure 11 shows the position of the headspace as the

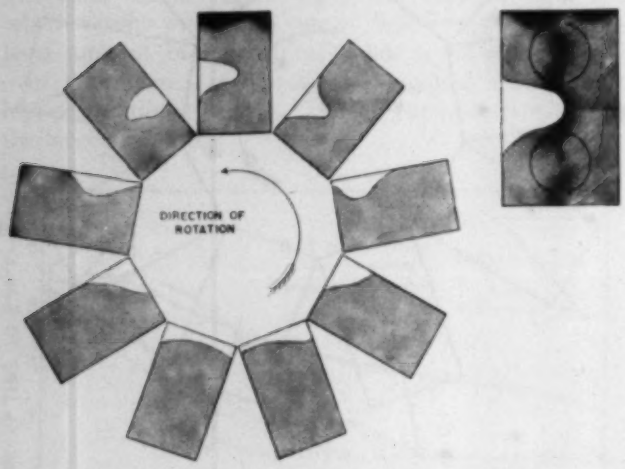

FIG. 11. Theoretical position and mobility of the can contents when the can is rotated end-over-end at optimum speed where CF = G. On the right the turbulence created when void space traverses through center of contents is illustrated.

can is being rotated when the centrifugal force equals the force of gravity. It will be noted that the headspace volume travels around the lower half of the can, passing through the center when in the vertical top position. The headspace volume changes its position from one side of the can to the other in a direction opposite to the direction of rotation as the can passes over the vertical dead center.

Just how the headspace volume passed through the can contents was not fully determined until a special apparatus (Figure 12) was constructed whereby a glass bottle containing a liquid could be spaced from the axis, and observed when rotated by hand.

It was observed, when rotating the glass bottle at low speeds, that the headspace volume followed around the walls of the bottle and crossed over at the top ver-

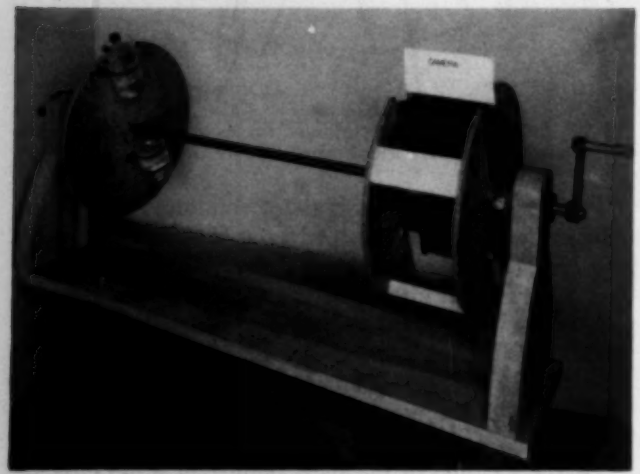

FIG. 12. Experimental equipment for motion picture studies of movement of can contents during end-over-end rotation at varying speeds.

tical position (due to the reversal of the direction of the resultant force) causing a splash or wave to be formed. At higher speeds the void space could not reach the top of the can and there appeared to be a separation of the water at the focal point. Due to the speed of rotation, it was difficult to observe this until a white ping-pong ball was placed in the bottle and then it was clearly evident that the ball could be made to pass through and across the liquid at selected positions depending upon speed of rotation.

Subsequently a movie camera was secured to a disk opposite the bottle and rotated in unison with it while exposing the film. These pictures verified the previous conclusions. When the centrifugal force is equal to the force of gravity, the conditions as shown in Figure 13 were observed. The center of the can under these conditions is the focal point or area of minimum force.

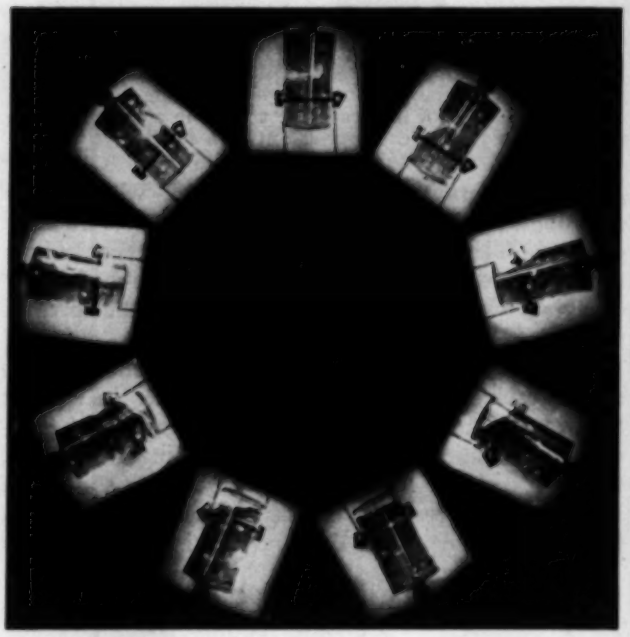

FIG. 13. Actual motion pictures of the movement of the can contents and the position of the headspace volume during end-over-end rotation at a speed where CF = G.

It was found that by selecting the proper speed the headspace volume could be made to pass through the liquid at various levels and when the speed is such that the centrifugal force equals the weight of the liquid contents, the headspace volume passes approximately through the center of the can. This was also found experimentally to give maximum turbulence within the can contents, resulting in the greatest rate of heat penetration.

This was considered important because it showed that for the maximum rate of heat penetration, the headspace volume must be made to pass through the approximate center of the contents of the can. Thus the greatest mobility of the contents is produced and it is possible to achieve high temperature processes for various canned foods in the shortest possible time.

In the above studies the optimum rotational speed where CF = Gravity is easily calculated from the simple formula $RN^2 = 35{,}196$, wherein R is the dis-

tance from the axis of rotation to the center of the can's contents, and N is the speed of rotation. In the cases of R-4 rotation (2-inch radius) using a 300 x 314 size can, N equals 132 r.p.m., for R-7 rotation (4-inch radius) N equals 94 r.p.m., and for R-8 (6-inch radius) N equals 77 r.p.m. Obviously viscosity is a factor in the mobility of the contents of a can and should affect the theoretical optimum speed of rotation. Using tomato pulp of varying viscosities a curve showing the relation of viscosity on the optimum speed of rotation (R-4) is illustrated in Figure 14. In order to allow

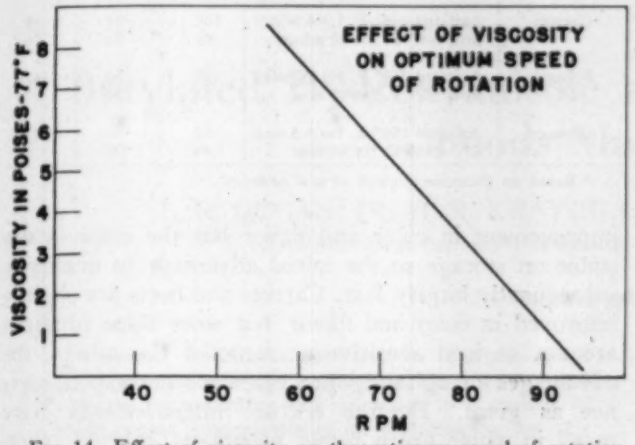

FIG. 14. Effect of viscosity on the optimum speed of rotation (end-over-end) in 307 x 409 size cans containing tomato puree, as determined by the most rapid rate of heat penetration.

time for the headspace volume to travel around the lower half of the can and cross through the center for more viscous products, the speed of rotation must be decreased for optimum conditions.

End-over-end rotation was further studied for the larger cans, such as 404 x 700 and 603 x 700 size cans. Figure 15 compares rotation of 603 x 700 size cans of

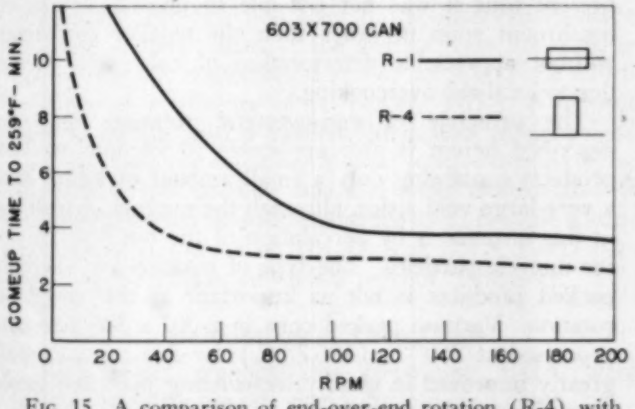

FIG. 15. A comparison of end-over-end rotation (R-4) with rotation along the long axis of the can (R-1) at varying speeds on the rate of heat penetration in 603 x 700 size cans of water.

water end-over-end (R-4) with rotation along the longitudinal axis (R-1) with respect to come-up time to 259° F. (126.1° C.). As in the case with the smaller can sizes, R-4 was found to be the superior means of agitation, particularly at moderate rotational speeds. In this case the theoretical optimum speed of rotation (N) where centrifugal force equals gravity for the 603 x 700 size can radius 3½ inches) is 101 r.p.m.

Up to this point data has been presented comparing rates of heat penetration into cans of water undergoing various means of agitation as well as illustrations of what occurs when end-over-end type of rotation is used. Table 1 shows data comparing the length of

TABLE 1

Sterilization By Agitating vs. Conventional Process

A Comparison of the Effects of End-Over-End Type of Agitation (R-4) with Conventional Still Processes on the Length of Process Required for Various Canned Foods.

Product	Can Size	Process			
		Agitated		Conventional	
		Time	Temp.	Time	Temp.
		Min.	*° F.*	*Min.*	*° F.*
Peas	307 x 409	4.9	260	35	240
Carrots	307 x 409	3.4	260	30	240
Beets—sliced	307 x 409	4.1	260	30	240
Asparagus—spears,	307 x 409	4.5	270	16	248
cuts and tips	307 x 409	4.0	270	15	248
Cabbage	307 x 409	2.75	270	40	240
Asparagus—spears					
brine packed	307 x 409	5.2	260	50	240
brine packed	603 x 700	10.0	260	80	240
vacuum packed	307 x 306	5.0	260	35	250
Mushroom Soup	603 x 700	19.0	260	....	....
Evaporated Milk	300 x 314	2.25	260	18	240

process employing end-over-end rotation with conventional still processes for various canned food products. As you may expect, there was a considerable decrease in process time with a corresponding improvement in quality of the agitated products as compared to those given a conventional still process. This was particularly true for products packed in the larger can sizes (603 x 700 size cans).

As previously mentioned, the practicability of employing higher temperatures of processing than conventionally in use is greatly dependent upon the heating characteristics of the product. "Burn on" of the product on the inner walls of the container and overcooking of the outside portions of the product farthest away from the "cold spot" in the can definitely limits the maximum temperature which can be successfully used. Also, an increase in processing temperature magnifies the differences due to possible variations in packing conditions which would tend to affect the rate of heat penetration from can to can, thus making the establishment of adequate processes more difficult. For these reasons, in commercial practice, retort temperatures for non-agitated products heating mainly by conduction seldom exceed 240° F. (115.6° C.) and those by convection, 250° F. (121.1° C.).

In the studies employing end-over-end rotation, processing temperatures ranged from 212° to 300° F. (100.0° to 148.9° C.) and in a few instances as high as 350° F. (176.7° C.). From comparisons of heat transfer rates for a number of products, it appeared that the maximum practical temperature for agitating processes for most products should not exceed 270° F. (132.2° C.). This conclusion was not reached because of localized "burn on" or "overcooking" of the product in the can, but from a consideration of the accuracy of establishing adequate processes as affected by variations in packaging conditions, which in turn affect the rate of heat transfer from can to can. Efficient agitating processes tend to smooth out the variations in packaging

conditions thereby allowing the use of higher retort temperatures with equivalent or better control of heat penetration rates as compared to still processes at lower temperatures.

The amount of thiamine destruction in canned foods has often been used as an index of the chemical changes taking place during processing. The rate of thiamine loss in peas as affected by the variables of time and temperature during thermal processing is shown in Figure 16. From these data it would be logical to conclude that high-short processes as accomplished by

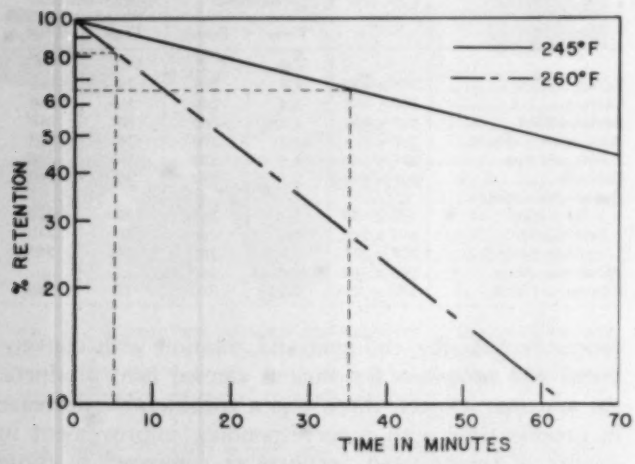

FIG. 16. The comparative rates of thiamine retention in peas as affected by processing time and temperature.

efficient agitation would greatly enhance the retention of thiamine and improve the quality characteristics of canned foods. Thiamine retentions for a number of products given a high-short process under agitating as compared to conventional still processes are shown in Tables 2 and 3. It will be observed that the differences

TABLE 2

Thiamine Content of Agitated vs. Conventionally Processed Corn and Peas

A Comparison of the Effects of End-Over-End Type of Agitating Process (R-4) with Conventional Still Processes on the Thiamine Retention in Various Canned Foods.

Product	Can Size	Process	Thiamine content mg./100 gms. of can contents
Corn, Whole Kernel in Brine	307 x 409	Agitated 260° F. for 6 min.	0.061
		Still 240° F. for 40 min.	0.025
Corn, Whole Kernel Vacuum Pack	307 x 306	Agitated 260° F. for 5 min.	0.082
		Still 250° F. for 35 min.	0.034
Peas	307 x 409	Agitated 270° F. for 5 min.	0.204
		Still 240° F. for 35 min.	0.156

in thiamine content immediately after processing still prevail after six months' storage at room temperature.

A listing of products definitely improved by agitating processes at 260° to 270° F. (126.7° to 132.2° C.) over conventional processes include whole grain corn (vacuum and brine pack), pureed vegetables in all but the 202 x 214 can size, concentrated and creamed soups, various milk products, and most vegetables. In the latter group of products, asparagus and peas show

TABLE 3

Thiamine Content of Agitated vs. Conventionally Processed Canned Vegetables (307 x 409 Size Cans)

A Comparison of the Effects of End-Over-End Type of Agitating Process (R-4) with Conventional Still Processes on the Stability of Thiamine During Storage in Various Canned Foods.

Product	Process	Percent Rentention *		
		Initial	1 Month	6 Months
Peas	Agitated 260° F. for 5 min.	80	69	73
	Still 240° F. for 35 min.	64	67	59
Green Beans	Agitated 260° F. for 5 min.	85	82	68
	Still 240° F. for 20 min.	54	56	49
Carrots	Agitated 260° F. for 6 min.	100	94	98
	Still 240° F. for 30 min.	69	72	70
Spinach	Agitated 260° F. for 20 min.	52	50	41
	Still 252° F. for 45 min.	33	36	27
Cabbage	Agitated 260° F. for 4.5 min.	67	50	35
	Still 240° F. for 40 min.	44	32	29

* Based on thiamine content of raw product.

improvement in color and flavor but the color is not stable on storage so the initial advantage in quality is subsequently largely lost. Carrots and beets are slightly improved in color and flavor, but since these products are not as heat sensitive as some of the others, the advantages of agitating processes are correspondingly not as great. Definite texture improvements were noted in whole green beans, asparagus, cabbage, cherries, and strawberries. Whole grain corn (brine or vacuum packed) when processed under agitation showed the greatest improvement in color and flavor as compared to the conventionally processed product. Agitated processed whole grain corn was very similar to cooked fresh corn. In the case of cream of mushroom soup, it was possible to process this product in No. 10 size cans using end-over-end rotation, and obtain color and flavor equivalent to that in the No. 1 size cans now being produced by conventional processes. Up to the present time it was not possible to process cream of mushroom soup in other than the smaller can sizes without appreciable deterioration of color and flavor due to localized overcooking.

The principle of end-over-end rotation such as described herein is also applicable to vacuum packed products containing only a small amount of liquid and a very large void space, although the method of heating in this instance is by percolation of the hot liquid over the discrete particles. The type of rotation for vacuum packed products is not as important as the speed of rotation. Vacuum packed corn in a 307 x 306 size can processed at 260° F. (126.7° C.) for five minutes was greatly improved in quality, resembling blanched fresh corn prepared in the home.

Summary

A new principle for agitating canned foods has been presented, which enables the use of higher temperatures and shorter times than are now conventionally employed for processing these foods. End-over-end rotation around an axis external to the can at proper speeds was found to be the most efficient type of agitation. In using this principle of rotation, improved quality and thiamine retention were observed for many products.

This is particularly true with some products in the larger can sizes which have not been previously possible to sterilize without undesirable effects on their quality.

Acknowledgment

The authors wish to acknowledge the assistance rendered by Mr. F. W. Parrin, Mr. J. R. Newman and Mr. S. Medoff in conducting the experimental work reported in this paper and to Mr. P. E. Pearson and Mr. J. M. Royal for designing the laboratory equipment which made this study possible.

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Butylated Hydroxyanisole as An Antioxidant for Fats and Foods Made with Fat[a]

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Butylated hydroxyanisole and its mixtures with other antioxidants and citric acid have been found effective for retarding rancidification in a number of foods whose susceptibilities to stabilization by this antioxidant have not been evaluated previously.

In 1948 the American Meat Institute Foundation announced the development of a new antioxidant for animal fat. This antioxidant contains butylated hydroxyanisole (BHA) which is essentially a mixture of the 2- and 3- tertiarybutyl-4-hydroxyanisoles. Butylated hydroxyanisole was shown to be much more effective than other antioxidants in retarding the development of rancidity in foods made with lard *(2, 3, 4, 6)*.

This paper describes the application of BHA to other uses in the food field and some of the observations made in these studies. Most of the studies were made using the synergistic combination known as AMIF-72 which consists of a mixture of 20 percent BHA, 6 percent propyl gallate, and 4 percent citric acid in propylene glycol. This combination is now used extensively by the industry to stabilize lard and other animal fats. It is generally used in such quantities as to provide a concentration in the fat of 0.01 percent BHA, 0.003 percent propyl gallate, and 0.002 percent citric acid.

Stabilization of Corn Chips

Antioxidant combinations containing BHA were used to stabilize the oils used in frying corn chips.

The corn chips were fried by a commercial processor who used corn oil and peanut oil, each of which had been stabilized with BHA, hydroquinone, and citric acid. The stability of each oil was increased but not quite doubled as measured both by the Active Oxygen Method *(1)* and by the Schaal Oven Test at 145° F. (62.8° C.). The corn chips fried in the stabilized oils were more resistant to rancidity. When peanut oil was used, the stability of the chips was more than doubled by use of the antioxidant (Table 1).

TABLE 1

Stabilization of Corn Chips and Frying Oils

Oil and Antioxidant Used	Stability of Oil		Stability of Corn Chips
	A. O. M. Hrs.	Schaal Oven Test, Hrs.	Schaal Oven Test, Hrs.
Corn oil	10	54	117
Corn oil plus 0.025 percent AMI-72 [b]	19	83	203
Peanut oil	15	54	98
Peanut oil plus 0.025 percent AMI-72	26	95	261

[b] AMI-72 0.025 percent provides a concentration in the oil of 0.02 percent Butylated Hydroxyanisole, 0.003 percent Hydroquinone, and 0.002 percent Citric Acid.

The Schaal Oven tests on the chips were accompanied by taste panel tests after 9 and 12 weeks storage at room temperature in sealed cellophane bags. After 9 weeks, the chips fried in unstabilized oil were rancid and the bags containing them had strong rancid odors. The chips fried in stabilized corn oil were slightly rancid at 12 weeks and the inside of the bag had a pronounced odor of rancidity, while those fried in stabilized peanut oil were still fresh tasting, and the inside of the bag had no rancid odor.

This study and that of Magoffin and Bentz *(5)* on potato chips show that the stability of vegetable oils and mixtures of lard with vegetable oils can be improved by use of BHA and antioxidant combinations containing it and that foods fried in stabilized vegetable oils can be expected to have greatly improved resistance to rancidity. The surface of the container was apparently important to the onset of rancidity in this case. Rancidity apparently ensued much sooner in the fat that had rubbed off onto the surface of the bag than in the fat still in the fried food.

Stabilization of Nuts

Development of rancidity in both the raw and the roasted nuts is one of the most important problems in

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 23, 1950.

the storage of nuts and nut meats. Preliminary studies were made to determine the effect of antioxidants containing BHA on the keeping time of raw nuts.

The almonds, pecans, and English walnuts selected for the test were divided into 100-gram lots, and the antioxidant mixture was sprayed on in an alcoholic solution. An equal quantity of alcohol containing no antioxidant was sprayed on the control sample. After the alcohol evaporated, the samples were put into loosely capped screw-top jars and tested for organoleptic rancidity under accelerated storage in an oven at 145° F. (62.8° C.). Data in Table 2 show that the antioxidant was quite effective. The keeping time of almonds was increased 3-fold, that of pecans by almost 2.5-fold, and that of walnuts 6-fold.

TABLE 2

Keeping Time of Nuts Stabilized with AMI-72

Nuts and Antioxidant Used	Schaal Oven Test, Hrs.
Almonds	2098
Almonds plus 0.015 percent AMI-72	6400
Pecans	635
Pecans plus 0.015 percent AMI-72	1571
Walnuts	154
Walnuts plus 0.015 percent AMI-72	962

Fat Rancidity and Vitamin Losses in Dry Dog Food

Samples of a commercial dog biscuit were prepared containing 12.5 percent fat added as lard stabilized with AMIF-72 as compared to the 4-5 percent fat commonly found in dry dog feeds. The biscuits contained vitamin A added in fish liver oil. A quantity of the vitamin was lost or destroyed in the preparation process but it is especially interesting to note the rate of loss of vitamin A with time under accelerated storage conditions.

Table 3 shows that more vitamin A survived the preparation process in the sample treated with the antioxidant than in the non-stabilized sample. The superiority of the stabilized sample is also demonstrated by the length of time required to become rancid and in the amount of vitamin A available in the sample at a given time during the storage period. After one week of storage, the non-stabilized sample was rancid, and the vitamin A was reduced from 15.95 to 2 units per gram, while the stabilized sample was not rancid and retained its vitamin A content unchanged from the original assay. The stabilized sample required 4 weeks to become rancid at 145° F. (62.8° C.). At that time the vitamin A content was one unit higher than that of the non-stabilized sample when it became rancid after one week. The regular-formula dog biscuits with no added fat or stabilizer became stale in one week but failed to become rancid in 6 weeks. The vitamin A content, however, was reduced to zero in that period of time.

These data show the effect of the antioxidant both in prevention of rancidity and in vitamin A retention of the dog biscuits.

Stabilization of Lard

The initial stability of six different brands of shortenings purchased on the market and that of food products made from them were determined as was that of a good steam rendered lard and of the same lard that had been stabilized with AMIF-72. Results of these tests are shown in Table 4.

TABLE 4

Experimental Results Obtained on Shortening and Lard

Shortening	A. O. M. Stability, Hrs.	Schaal Oven Test, Hrs.	
		Crackers	Pastry
Brand No. 1	125	1002	977
Brand No. 2	44	522	335
Brand No. 3	97	912	743
Brand No. 4	22	600	407
Brand No. 5	45	408	341
Brand No. 6	55	630	473
Lard (No antioxidant)	5½	240	34
Lard plus 0.025 percent AMIF-72 [g]	92	1234	694

[g] The 0.025 percent AMIF-72 provides a concentration in the lard of 0.02 percent BHA, 0.003 percent propyl gallate, and 0.002 percent citric acid.

These data show that the use of the antioxidant combination AMIF-72 in a good lard provides stability of the lard, and crackers and pastry made with lard, comparable to those of the best hydrogenated vegetable shortenings.

Chicken Fat

The antioxidant AMIF-72 has been found useful in stabilizing chicken fat. This suggests that it would likewise be suitable for other poultry fat and poultry products.

A producer of chicken products made a rendered chicken fat which was consistently in the 3 hour range of A.O.M. stability. By the use of AMIF-72 in the rendering process, he was able to produce a fat with a lower original peroxide value (O.P.V.) and an A.O.M. stability of 20 or more hours. A typical example is shown in Table 5. The antioxidant was added at the time when the fat was put into the rendering tank.

Stabilized Wrapping Papers

The role of a wrapper or package for fats or fatty foods is of extreme importance. It is on the wrapper or package that first signs of rancidity can often be detected. This is frequently due to the greater surface

TABLE 3

Keeping Time and Vitamin A Losses in Dog Biscuits Stored at 145° F. (62.8° C.)

Description of Sample	Vitamin A Added	Original Assay [e]	Assay [e] after					
			1 week	2 weeks	3 weeks	4 weeks	5 weeks	7 weeks
Dog Biscuits [c]	.....	3.95	.....	.....	.....	.....	.....	0.0
Dog Biscuits with 75 lbs. lard in 600 lbs.	20.83	5.95	2.05 [f]	1.80	1.28	0	.....	.....
Dog Biscuits with 75 lbs. lard in 600 lbs. and with 6.25 gms. of AMIF-72 [d] in lard	20.83	7.45	7.45	6.80	4.84	3.05 [f]	1.80	.....

[c] Stale at 7 days but not rancid at 6 weeks.
[d] AMIF-72—mixture of 20 percent butylated hydroxyanisole, 6 percent propyl gallate, and 4 percent citric acid in propylene glycol.
[e] Units per gram.
[f] Rancid.

TABLE 5

Effect of Added Antioxidants on Chicken Fat

Sample	Free Fatty Acid, percent	O. P. V.[a]	A. O. M. Stability, Hrs.
Rendered Chicken Fat	0.82	6	3
Chicken Fat rendered in presence of AMIF-72 [b]	0.98	3	20½

[a] O. P. V.—Original Peroxide Value.

[b] The AMIF-72 was added in a proportion to provide a concentration of 0.01 percent BHA, 0.003 percent propyl gallate, and 0.002 percent citric acid.

contact with air. At other times the reason is in the presence of substances in the paper or other material which can act as pro-oxidants to promote rancidity in the absorbed or rubbed-off fat.

To learn whether or not BHA-treated wax or parchment papers would be effective in delaying rancidity a series of tests were made by using a parchment paper prepared from paraffin wax containing 0.02 percent BHA. The BHA was found to be readily soluble in warm mixtures of the mineral oils and paraffin waxes commonly used for treating paper to be used as wrappers and packages for fatty foods. The tests comprised of organoleptic determinations of the rancidity of lard films on treated and untreated parchment paper, of lard cubes in folded packages of treated and untreated paper, and of chunks of lard in sealed packets of each of the two papers. Another test was made by evaluating the keeping time of freshly prepared potato chips in both closed and open bags made from parchment paper of the stabilized and the unstabilized type.

The lard films were prepared by placing a drop of melted unstabilized lard on squares of parchment paper and letting it flow around on the paper until it spread out to a very thin film. The paper squares were placed flat with the lard film side up on the bottom of clean opal ointment jars having screw tops. The jars were stored in an oven at 145° F. (62.8° C.) and smelled daily. Evaluation was difficult because of a tendency for all odor to disappear near the time for rancidity to be noted. The lard on the parchment paper prepared with BHA-treated wax required almost twice the length of time to become rancid as did the lard on the untreated parchment (Table 6).

TABLE 6

Effect of Antioxidants on the Stability of Lard Films on Parchment Paper and of Potato Chips Stored in Such Paper

	Stability of Lard		Stability of Potato Chips	
	Schaal Oven Test		Schaal Oven Test	
	Untreated Paper	Treated Paper	Untreated Paper	Treated Paper
Lard films	66 Hrs.	128 Hrs.	.....	.....
Cubes	3 Mos.	4 Mos.	.....	.....
Packets	5 Mos.	6 Mos.	.....	.....
Open Bags	.....	.....	112 Hrs.	121 Hrs.
Sealed Bags	.....	.....	113 Hrs.	120 Hrs.

Folded packages were made from each kind of parchment in such manner that they would fit in the compartments of an ice-cube tray. Melted unstabilized lard was poured in, the lard chilled, and the packages folded over the cubes. The cubes were placed in clean opal ointment jars with lids and held at room temperature storage. There was a keeping time advantage of one month for those cubes in the treated parchment. A similar advantage for treated parchment was found when chunks of lard were sealed with wax between two sheets of parchment and tested in the same way as the cubes.

Small bags were prepared with each kind of parchment and partially filled with freshly prepared potato chips fried in lard. Some of the bags were sealed at the top, some were left open, and all were put into an oven at 145° F. (62.8° C.). There was no advantage from sealing the bags as the chips became rancid at essentially the same time in both closed and open bags. Those in the bags made from BHA treated parchment required a few hours more to become rancid than did those in the bags made from untreated parchment.

BHA is currently used in various wax and parchment papers being used for wrappers and packaging materials in the meat and allied industries.

Taste and Odor

BHA has a characteristic aromatic odor when heated, and this odor can be detected by those acquainted with it when fat containing this antioxidant is heated to near the smoking point. However, even trained judges are unable to detect the presence of the antioxidant either in lard at room temperature or in foods made with fat containing BHA.

Taste panels have been conducted with crackers, pastry and bread all prepared with lard stabilized with BHA, or one of the combinations containing BHA. The bread was tested both fresh and toasted. As with the crackers and pastry, there was no evidence that judges could distinguish between the products made with stabilized lard and those made with non-stabilized lard.

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Summary

Butylated hydroxyanisole, an antioxidant for animal fats has been found to be effective in numerous additional applications. When used alone and in combination with propyl gallate and citric acid, it has been found useful in preventing rancidity in frying oils such as corn oil and peanut oil and in the foods prepared in these oils. It is effective in stabilizing nuts and chicken fat. It delays rancidity and vitamin losses in cereal products such as dry dog feeds. When used in a good lard, it gives stability performance both to the lard and to crackers and pastry made with the lard comparable with that of the best hydrogenated vegetable shortenings. Incorporated into oils and waxes used to treat paper for wrappers of fatty foods it aids in preventing rancidity in the fatty films formed on the container or wrapper. BHA and antioxidant combinations containing it impart no detectable flavor or odor to foods made with lard which has been treated with the antioxidant.

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Industrial and Legal Viewpoints

Chemical Agents and Residues in Foods: From the Viewpoint of the Consumer[a]

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Toward the consumer are directed all the efforts and responsibilities of producers, manufacturers, and regulatory bodies, whether governmental or otherwise. The consumer's lack of analytical facilities and her faith in those who supply her food make it imperative that the manufacturer bear the bulk of the burden of insuring safe, wholesome food, prepared in clean plants and with sound research behind the complete safety of any processes or added ingredients. The food technologist has a special opportunity to play a role in this field by guiding the top management toward even safer and more profitable approaches in supplying good food to our people.

Foods are substances necessary to build a human body and to keep it functioning normally. To the consumer, nothing in the physical realm could be more important for well-being and continued good health than the overall efficiency and safety of the food intake. No other environmental factor means so much to health, whether or not the consumer is aware of this fact. It is recognized today that death and disease are guided to a large extent by diet, and that the nature and capabilities of the individual and of his society can be correlated with the nutritional environment. Those who have anything to do with food carry both a grave responsibility and an equal opportunity to do good and to profit.

Chemical agents and residues in foods, to the consumer, means that something unnatural is there. Whether they were added for nutritional or functional value or both is not too important. Wetting agents, emulsifiers, stabilizers, improvers, preservatives, antioxidants, anti-biotics and others all mean to the consumer about the same thing: something added for some purpose. He or she has read, perhaps, of some dangerous things put into foods in years past, although for the most part has forgotten or never heard of monochloracetic acid in beer and wine, or thiourea in cut fruits. Nitrogen trichloride as a flour bleaching agent, or mineral oil in salad oils or dressings may be fresher in the consumer's mind. The D.D.T. milk scare was quite confined to the eastern coast (thanks to a considerate press) and emulsifying agents in bread and other foods do not seem to have raised any serious fears.

A Consumer is one who uses or converts the utility of foods. This disposition of food is the final goal of the food business; of the grower, producer, conveyor, regulatory agencies, and retailers. The effort of all is directed somehow toward the one who finally eats. Since the purchase and preparation of food is so largely in the hands of the homemaker, our interest in the consumer's viewpoint can be focused on the woman who buys, prepares and serves meals to the family. She is the one whose opinions count most with those who supply her.

No one, perhaps, has accurately described the average mind of the composite consumer, though by analyses based on education, nationality, sectional habits and other factors, she may be analyzed with some preciseness. There are several sources from which comes information about her thinking. Her actual food purchases at retail stores, the changes in food habits, the response to food promotions, the questions she raises with manufacturers, public health authorities and governmental agencies, the experience of those who have dealt with her for many years, her articulate expressions through consumer groups, are all valuable in describing her. Along with these sources, into which we have delved to some extent, are direct consumer surveys, aimed to analyze the viewpoints of this complex person. From all of these approaches, we can crystallize at least a few dominant characteristics which prevail with the great majority of those for whom food technologists actually work: the consumers.

First, let us repeat that the consumer is the goal toward which all forces and agencies in the industry of production, processing, advertising and selling are directed. The consumer determines the success or failure of food efforts, whether by whims, habits, or sound knowledge of food values. The homemaker buys food, first, to please her family and to give them health and

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 22, 1950.

strength. She buys to save preparation time and money, to elevate her social prestige on occasions, and to get all the flavor enjoyment possible from foods. She spends about one-third of her time on buying, preparing and serving food. She conforms to the likes and dislikes of the family in selecting foods, and once she knows their desires, her buying becomes largely a matter of habit and routine, more and more free from worry. As she gets better acquainted with prepared or semi-prepared products, she evaluates foods more and more by the time and expense of preparation. She has an abiding faith in her grocer, her baker, her butcher and her milkman. She trusts them and yet appreciates their limitations in the control of food items, especially packaged foods. She takes for granted that the foods she buys are wholesome, clean and free from harmful substances. Unconsciously, she depends on the manufacturer and producer to do right by her. She depends on brand names and what is behind them. Her reliance on the government and health officials to protect her on quality and safety may vary with current happenings such as publicized failures of manufacturers and processors to do this properly for her. She would like to feel that these outside agencies are not needed to watch over those who make, store, and deliver from the farm to the kitchen. She is also not aware that one of the main benefits of government control is to protect the good manufacturer from the other type.

Routine habits and confidence induce the homemaker to purchase largely from the same sources, the same brands and quantities from week to week. This repetitious purchasing relieves her of thought and worry. Though this is a stabilizing factor in the food industry, it becomes a barrier to the spread of knowledge about new products or foods which she has not previously bought. She is rather slowly, though surely, affected by advertising on new and improved foods or radical changes in old foods. In the variation of the appeals for quicker acceptability of new items lies the challenge to those who sell. War and emergencies of one kind or another, of course, are outside stimuli which make pronounced shifts in food habits.

It must be conceded, therefore, that today's shopper is busy and hurried and has little time to note more on the labels than the color and brand name. Where grandmother simply bought three pounds of rice, her granddaughter must choose from rice labeled "plain," "regular," "converted," "parboiled," "precooked," "malekized," "long white grain," "short grain," and a few more. Is it any wonder that she must have faith that everything in a package is safe? Even a chemist husband has not time to investigate the line for her.

She knows a little about acute food poisoning and less about chronic poisoning. She may have encountered acute toxicity with its dramatic features and be unaware of a cumulative poisoning which lacks such symptoms. She hopes that poisonous foods or substances can be avoided at any cost. Since her facilities for investigation are practically non-existent in her busy life, she must rest her case with those who supply her. She does not know, as Dr. J. R. Wilson, of the American Medical Association, says, that "One good, hard-working chemist can create more problems than ten toxicologists can solve." She must have faith that food suppliers will not exploit her and, in reciprocity, she will give loyalty to a brand, to a company and to the industry.

These are brief statements of the reaction of any human being who is helpless in protecting herself, but, in turn, generous in loyalty when she has been treated right. This is the simple psychology prevailing in the field in which the food manufacturer serves the American homemaker.

Now let us see how she might be expected to react to situations which touch more closely the subject of chemical agents and residues in food.

When a woman sees by the label that a food contains some new or unusual ingredient, what is her response? It is generally found that she shows an unexpected confidence in the manufacturer. About 50 percent of those women who do read labels tend to desire information on the new ingredient, and the great majority of this group would ask the grocer about it. A smaller number want to get advice from a doctor, while the others are inclined to go to local authorities, informed friends, or to forget it.

If two products on sale are alike except that she sees that one contains an unfamiliar ingredient, the majority will prefer the one without the new ingredient, although they may not refuse to buy if they have faith in the brand or manufacturer. It is quite apparent that an established brand has a confidence cushion to work on when added chemicals are announced.

When new, unfamiliar ingredients are noticed on a package, an outstanding majority accepts the product as safe and wholesome. This faith in the food and the supplier is a tribute indeed. This confidence, generally merited, of course, implies a great responsibility on the part of the food manufacturer to safeguard the consumer's interest by painstaking research and investigation on the safety of any added chemicals. And well do we all know that one bad apple spoils a barrel. Failure to protect her affords health authorities and other interested agencies a freedom of action that can and will destroy her confidence and replace it, perhaps, with active revulsion. For any food supplier to risk this avoidable hazard by any unsafe component is inconceivable from a business viewpoint alone.

Products being apparently the same, will the shopper buy a familiar or an unfamiliar brand? The outstanding preference here for the familiar brand is not surprising. She already knows the product, and this present knowledge along with habit, convenience and a disinclination to change keeps her with brands she knows. To the manufacturer, this means added responsibility to "play safe" with his brand in every conceivable way.

When a woman buys a food containing an added chemical, on what basis does she accept it as safe? Consumers seem to place greatest dependence on two factors, the manufacturer, and the federal, state or local health control. Many rely on both, with the thought that official agencies always watch over the manufacturer.

Food technologists are in the best position to carry this responsibility and to work toward that goal in food